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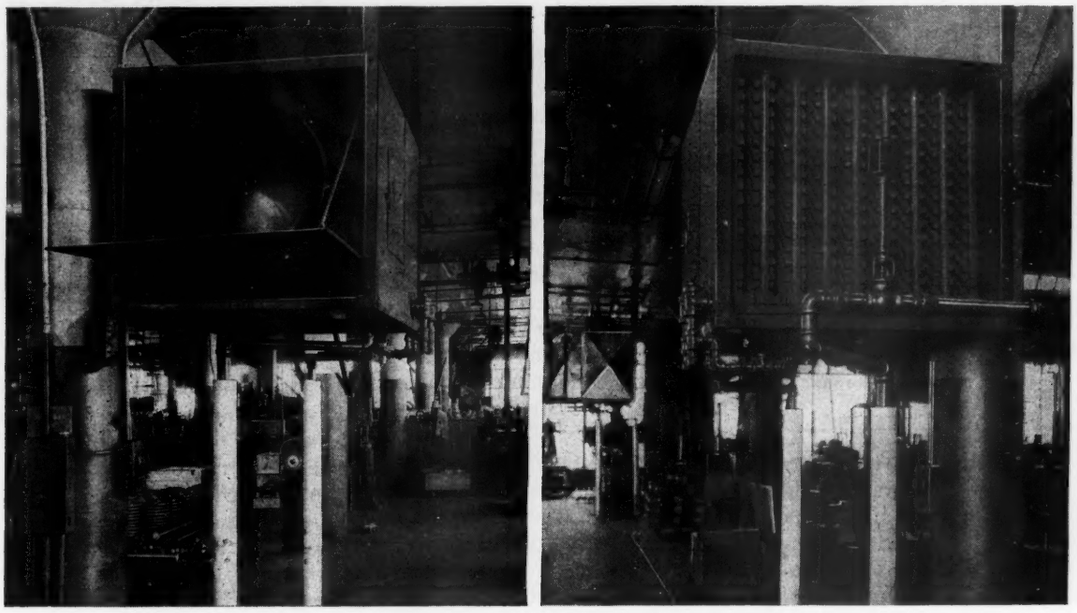


Each of these Ilg unit heaters is controlled through the Powers thermostat regulator on the inlet end of the cast-iron radiators, in the illustration at the right. The temperature of the incoming air thus regulates the amount of steam supplied to the radiators.

Applications of Unit Heaters in Industrial Plants

By FRANK E. GOODING
Associate Editor, Industrial Engineer

MAKING adequate and economical provision for heating the industrial plant, particularly in sections where men and women are employed, requires careful study and observation on the part of the executive who is responsible for this service. Correct heating means more than the computation of the heat losses and a determination of the number and size of radiating or heating elements capable of providing the necessary heat. Many plants with ample provision for heating are not comfortable, however, and do not afford good working conditions because the arrangement of the heating elements or units is not such that the heat is placed or used properly; some parts of the plant have too much heat, while others do not have enough.

Heat is necessary for comfortable operation and must be supplied at varying temperatures depending upon the type of work done. For example, women workers seated at light assembly tasks require the maintaining of slightly higher temperatures than where men are engaged in heavy and active work.

Industrial plant heating is usually accomplished by one of the following three methods, and commonly with the use of steam as the original source of heat. These methods are:

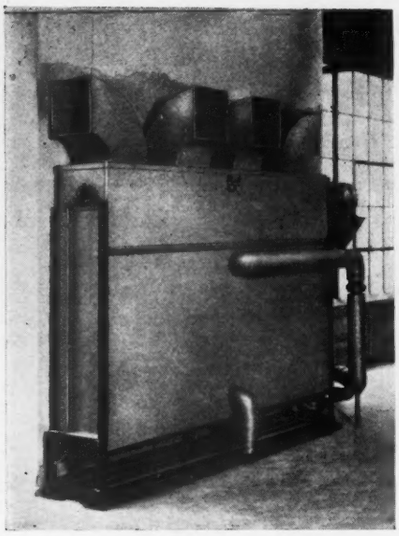
(1) Direct radiation by steam coils or radiators usually located along the walls or on the ceiling.

(2) Hot-air duct system with central steam coils, fans, and ducts to distribute the heated air.

(3) Unit heaters of various types, a complete installation for a plant or room consisting of a number of units each containing a fan and a source of heat.

As stated, radiators or steam coils for direct radiation are usually placed along the walls or on the ceiling and depend upon natural circulation due to the heated air, which has been in contact with the surface of the coil or radiator, rising and the colder air at the floor level replacing it. Frequently, this results in a hot, upper level of air and a cold floor level.

An open window or skylight or a draft caused by open doors or stairways will usually prevent the functioning of natural circulation. This makes direct radiation more difficult to control especially on mild days in the spring and fall when windows are

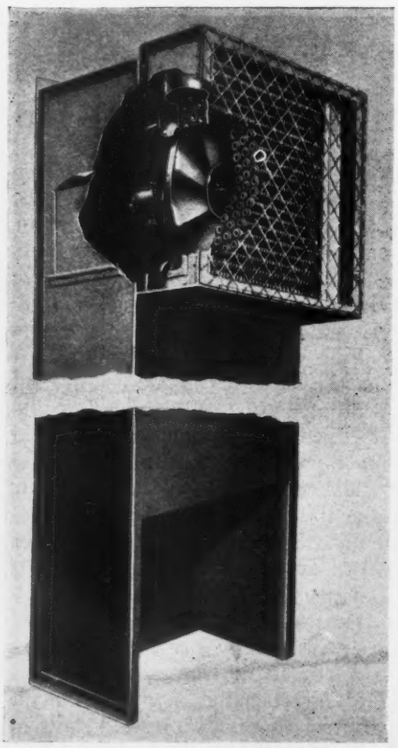


Floor-mounted unit heater with four outlets or diffusers.

Each outlet is supplied from an individual fan mounted on a long shaft and driven by the motor at the right. Cold air enters these York heaters at the floor level and is drawn through a high-pressure steam coil.

likely to be opened. In such cases the heat goes out of doors and the rapid circulation of cold air around the radiators results in the very uneconomical use of steam. It is not at all uncommon for heating, in such cases, to cost more during mild weather than in cold weather.

Heat regulators are used sometimes in connection with direct radiation to shut off the steam supply, but they are most successful in smaller



Floor-mounted unit heater with recirculating box.

The cut-away view of this ABC Venturi unit heater shows the construction of the high radiating, copper coils with extended fin surfaces. The recirculating box is used to draw the air from the floor and to give more complete circulation.

Modine Thermodine unit heater.

The condenser consists of a large number of flattened, vertical copper tubes rigidly held in position by a series of horizontal copper fins spaced and constructed so as to cause the air passing through to come in contact with the heat-radiating surfaces.

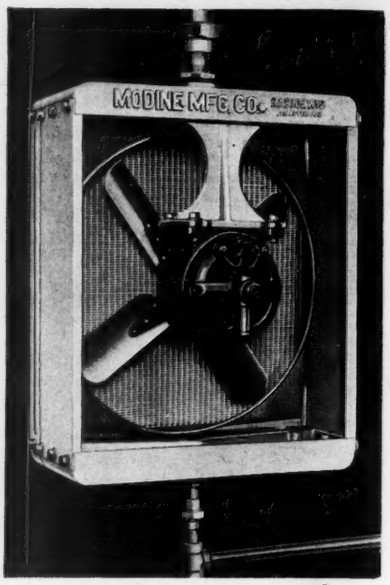
rooms where the heat is likely to be more uniform throughout, and fewer radiators are to be controlled by each heat regulator than in the large area of the workroom in the average industrial plant.

The use of a central heating unit, consisting essentially of a fan, steam radiators, and a system of sheet-metal ducts for distributing the heated air to various parts of the room or building, is also widely used in industrial heating. Such a system is usually tied in with the ventilation and is possibly necessary where it is desired to provide air of any special humidity or to wash and clean the air before using or recirculating. In such cases air washing and conditioning equipment is added to the system as previously mentioned.

One of the advantages of this method of heating is that the heated air is delivered where it is wanted. Thermostatic control placed in the inlet or outlet of the heating and conditioning equipment regulates the temperature of the outlet air by controlling the steam supply. Open windows, drafts, or strong side-winds affect the distribution of the heated air. The effect, however, is not so pronounced as when direct radiation from steam coils or radiators is used.

Frequently, due to changing conditions in industrial plants it is necessary to move heating ducts and rearrange them to accommodate even minor changes in machine layouts. In case the duct line is not located properly and does not distribute the air where it should go, it is often inconvenient and expensive to change it. Also, where overhead cranes are installed it is sometimes difficult to find a place to locate the ducts and it may be necessary to run them underneath the floor. A decided advantage of the duct system, however, is that it can be used to distribute cooled air through the building in summertime.

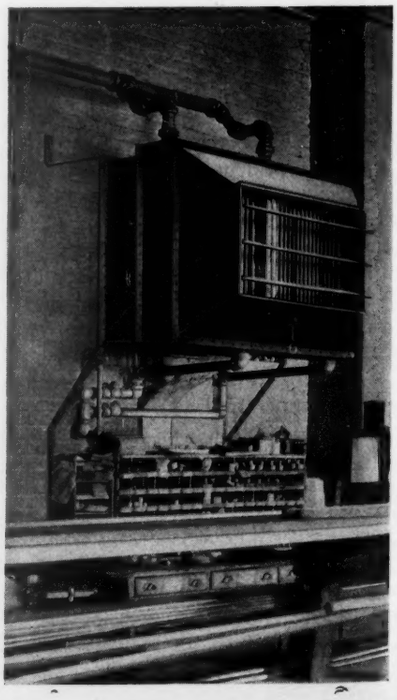
In buildings which were inadequately heated in the days when industrial heating equipment was not

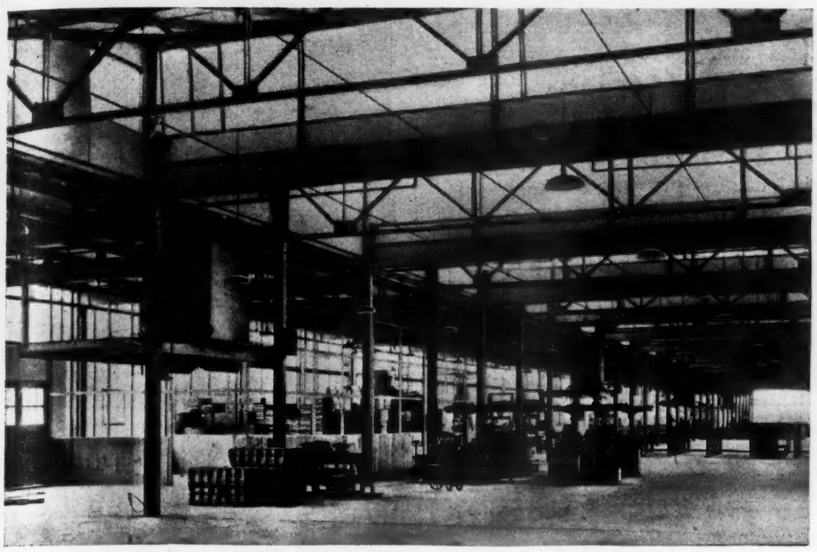


so scientifically designed, it had become the practice, in many cases, to install a number of open salamanders, usually burning coke or charcoal, in the cold spots. These were very undesirable not only on account of the smoke and gases but more particularly because of the fire hazard. In addition, this was a very inefficient means of heating, and did not in any way distribute the heat except by the natural drafts in the room.

Units should be mounted at least 20 to 30 in. from a wall.

This provides space for the circulation of the air to the inlet side of the heater. When wall-mounted, dual outlets are sometimes used to give wider distribution. This is an Autovent installation.





Here the heater is mounted on the platform and discharges heated air downward and away from the sawtooth roof

This shows one of 16 Skinner Bros. Inverted-type, steam coil heaters for ceiling mounting in one of the plants of the Westinghouse Electric and Mfg. Co.

The need for suitable heating equipment in the many buildings in which it was necessary to distribute a few such makeshift heating units around the floor, even though the walls were all provided with coils or radiators, led to the development of unit heaters.

A unit heater consists essentially of a fan and a source of heat. The principle involved is that, instead of having a large central heating unit with a system of ducts distributing the heated air to various points of the building before discharging into the room, a number of small units, each with its own heating unit and fan to distribute the air, are located at suitable points in the room. One of the big advantages of unit heaters lies in the elimination of the ducts, and so the unit does not require a large amount of power as is necessary for forcing the air through the ducts.

In general, unit heaters fall into some of the following classes: (*a*) The direct-fired type which may best be described as a pipeless hot-air furnace with a fan to circulate the air and distribute it about the room. (*b*) A system which includes a few large units with fan and steam or hot-water coils. (*c*) A number of small units, each with its fan and steam coil.

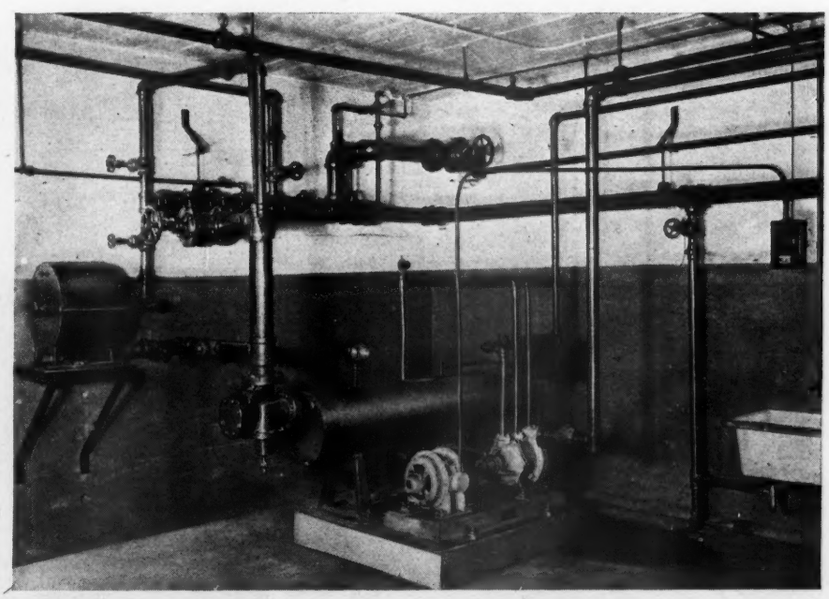
Steam is the medium commonly used for heating the air, although hot water is sometimes used. Also, in the types of direct-fired hot-air heaters mentioned, the heat is obtained from a fire, usually of coke, although the fire hazard has prevented this type of unit heater from gaining wide popularity. These units are used where there is no steam supply.

Direct-fired units are always floor-mounted. A number of the other types and makes of unit heaters are designed either to be mounted on the floor or suspended from the ceiling. Floor mounting is usually satisfactory where the ceiling is not over 15 ft. in height. When the ceiling is higher, and with monitor or sawtooth roof construction, it is often advisable to mount the heater on the ceiling. Ceiling mounting also conserves floor space.

In some cases the floor unit and the ceiling-mounted unit are almost identical except for the method of support, which usually consists of angle-iron legs either extending down to the floor or up to the ceiling.

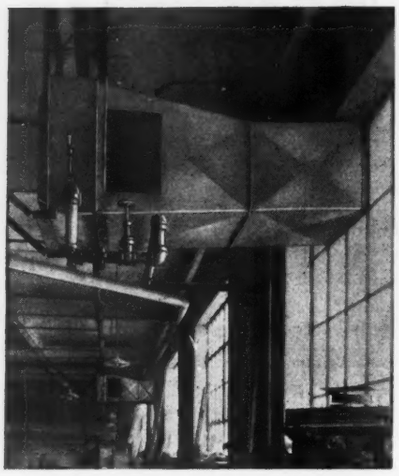
Because a unit is designated as floor-mounted it does not mean, however, that the heat is distributed at or near the floor. The heat should always be discharged above the level of the men's heads. The large floor-mounted units extend down to the floor. Sometimes the smaller units are provided with a floor intake or recirculating duct, as is shown in one of the illustrations on page 350. These recirculating ducts are used to draw the air directly from the floor and recirculate it instead of taking it in on a level with the discharged air, as is the case when no recirculating duct is used. Where the floor is very dusty, for example, it is generally better to withdraw the air for recirculation from the level of the fan than from near the floor. Sometimes duct connections are made to the outside instead of recirculating the air from within the room.

Some manufacturers recommend the use of recirculating boxes only where there is considerable height to the building to be heated, or where men are working at benches and are not in motion. There is a small differ-



Vacuum equipment for a battery of unit heaters

This Jennings Hytor vacuum heating pump (Nash Engineering Co., South Norwalk, Conn.) is connected on the steam return lines at the Ilg Electric Ventilating Co., Chicago, Ill., where the units illustrated at the beginning of this article are installed. The condensate is measured in the Detroit meter at the left (Central Station Steam Co., Detroit, Mich.) so that the amount of steam used for heating is known at all times. Steam is generated in oil-fired, low-pressure boilers.



This unit heater has an outside inlet

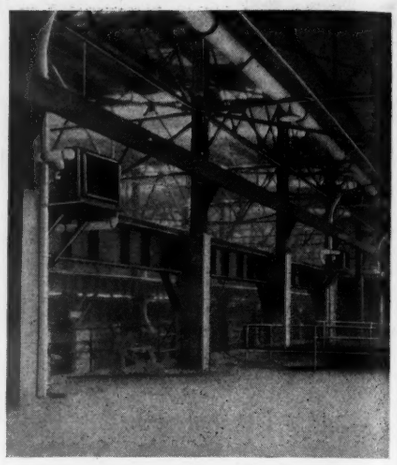
This Buffalo Breeze-Fin unit heater is arranged to draw air from the outside or to recirculate from the inside, as desired. Sometimes overhead units are provided with ducts extending to the floor for recirculation.

ence, it is said, between the temperature at the ceiling and floor, because the lower strata of air are kept in circulation, when return air connections such as these recirculating boxes are used. In some instances recirculating connections are also justified as a means of supporting the unit. Frequently it is necessary to mount the unit on a wall and something in the form of a platform or support must be used; these recirculating connections also serve this purpose. In some cases duct or recirculating connections are used with ceiling-mounted units as well.

Practically all manufacturers of unit heaters provide units which contain either cast-iron or steel-pipe coil radiators or coils made up of special tubes with expanded fins such as the Aerofin, giving an extended surface with high-radiating capacity although light and strong. The coils are offset or staggered to prevent the air from having too easy or free a path past the radiating surfaces. Ordinarily radiators and the special finned coils are used with low-pressure steam. One type of special finned coil may be used with steam pressures up to 150 lb. per sq.in., it is said. For high-pressure steam, coils of steel pipe or high-pressure radiators are used. However, a very large proportion of industrial heating systems use low-pressure steam. Units with the cast-iron radiators are larger than units of similar rating with coils of finned construction and high radiating capacity.

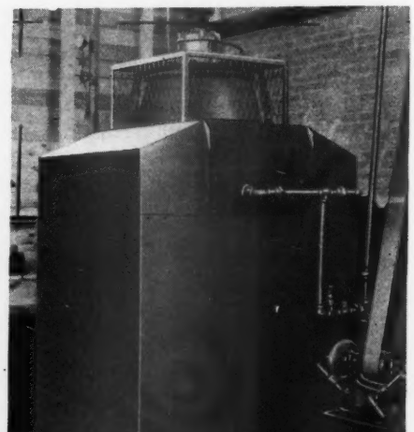
Examination of the various types of unit heaters illustrated in this article will indicate a rather wide use of the propeller type of fan, although some units use the multiblade blower type or other types of fans.

Propeller fans and the small



Unit heaters do not occupy much space

Here these Buffalo unit heaters are mounted on the building columns in between two crane runways. These are turbine-driven units using the exhaust from the turbine to heat the air.

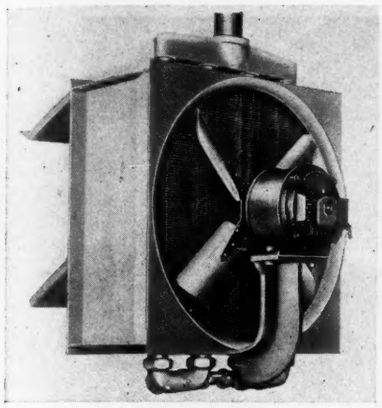


Two installations of heaters in the Schenectady works of the General Electric Co.

These heaters were built by the L. J. Wing Mfg. Co. Only ceiling-mounted and horizontal-type unit heaters are built by this organization. Notice in these two illustrations the difference in the direction of the diffusers on account of one being built for a low ceiling to give a wide angle of distribution and the other, in the peak of the ceiling, with a sharp angle downward.

This unit heater discharges heated air horizontally in all directions

The fan at the top of this new Clarage floor-mounted heater is mounted with the shaft vertical instead of horizontal, as in many of the other types of unit heaters. A companion Clarage unit, inverted, however, is used for mounting on the ceiling. Special copper radiating coils are used.



Unit heater with wedge core radiator

This Buffalo Breeze-Fin unit heater is is a special, extended-surface, high-radiating-capacity unit. The steam section of the radiator is wedge-shaped with aluminum fins extending at right angles and held in metal-to-metal contact by springs. This unit, it is said, can be used with steam up to 150-lb. pressure.

blowers used require a comparatively small amount of power to operate and in the case of several manufacturers, the largest unit made requires a 1-hp. motor or smaller. The smaller sizes of unit heaters are frequently operated from the lighting circuit.

With propeller-type fans it is necessary to pass the air alongside the motor, in that the fans are direct connected. With some makes of unit heaters the propeller fan is on the inlet so that the cooler air passes the motor. In other types the propeller fan is placed on the outlet where the motor is exposed to the direct heat of the air. In such cases special provision must be made for ventilating the motor, to keep it cool. Where blowers are used the motor is not in the line of circulation.

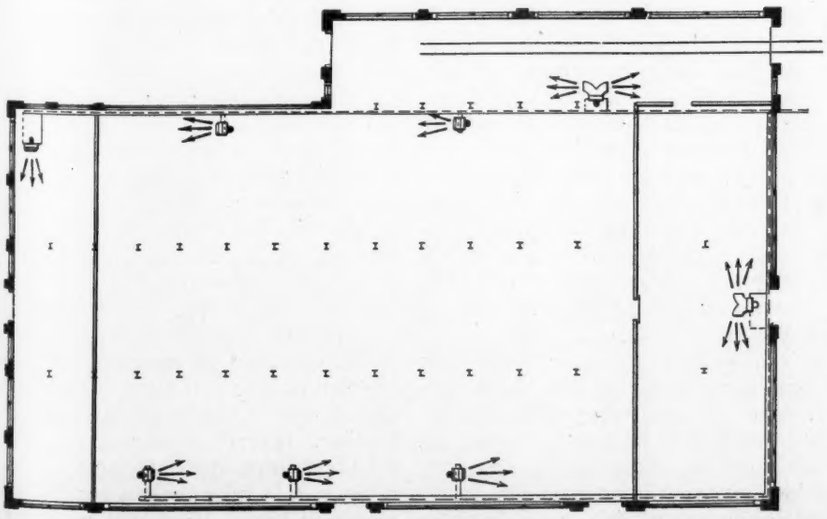
Where it is necessary to place a unit heater in such a position that men are working in front of it, it is necessary to use deflectors or louvres to carry the heated air above their heads. In other cases it is advisable to use these deflectors so as to send the air down, as for example in case of a high ceiling. By constructing special outlets, as shown in several of the illustrations, it is possible to divide the discharge so that it will go in more than one direction. This arrangement is frequently used where it is necessary to place the unit alongside one wall or near the end or short side of a building and depend on it to heat that entire end or side.

Unit heaters, the same as any other type of heating equipment, are designed to overcome the heat loss computed on a B.t.u. basis. These computations take in the amount of glass and other wall, ceiling, or roof area, and other sources of radiation and heat loss. The method of computation is too detailed to explain here but is given in any handbook covering heating. However, the size and shape of the room, type of construction, type of windows, and other special factors influence the rating, type, number, and location of the various units to such an extent that it is advisable to consult with the manufacturer of the unit and obtain his recommendations on these points before making an installation.

The return line of the steam condensate may either be coupled to an atmospheric return through a trap or to a vacuum system. Because plants should know their cost of operation it is well to meter or measure in some way the condensate so as to know the cost of heating. This is not always done but without some knowledge of the total cost, and of the comparative cost over a period, expensive losses may occur for some time without being discovered.

Suggested arrangement of unit heaters

Notice that special care is taken to force the heated air into the exposed corners at the right end. If this plant had an extra-high ceiling or was much wider, additional units might be necessary in the center.



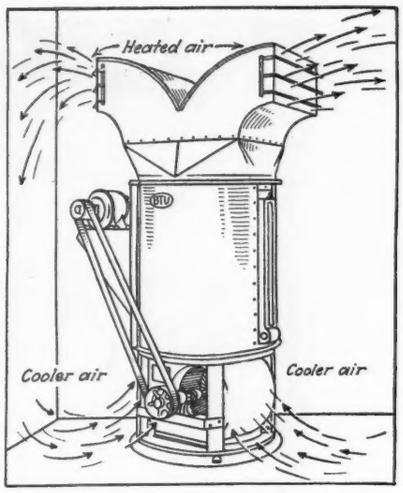


Diagram of operation of the Boyley Thermo Unit

This unit uses a multiblade fan belted to a motor. Inverted units are used for high ceilings.

One of the best methods of controlling the cost of heating is through the use of some method of thermostatic control which operates or shuts off the unit according to the temperature. Thermostatic control units may be obtained either to control the power circuit to the fan or to close or open the steam line. A Powers regulator for controlling the steam line is shown in the illustration at the right at the beginning of this article on page 349.

The regulator shown is placed about 6 in. away from the radiator at the inlet end of an Ilg unit heater. With the air in forced circulation the radiator does not affect the regulator even at this short distance. The temperature of the air in the room as it passes the regulator operates the diaphragm which opens or closes the steam line to the radiator. Thus the temperature of the air in the room controls the amount of steam supplied to heat the air as it passes through the heater.

In the plant in which this photograph was taken the thermostat is set to operate at an inlet temperature of about 68 deg. F. The temperature of this inlet air is naturally the temperature of the room. In case the power to the fan should be shut off for any reason the circulation would

(*Please turn to page 374*)

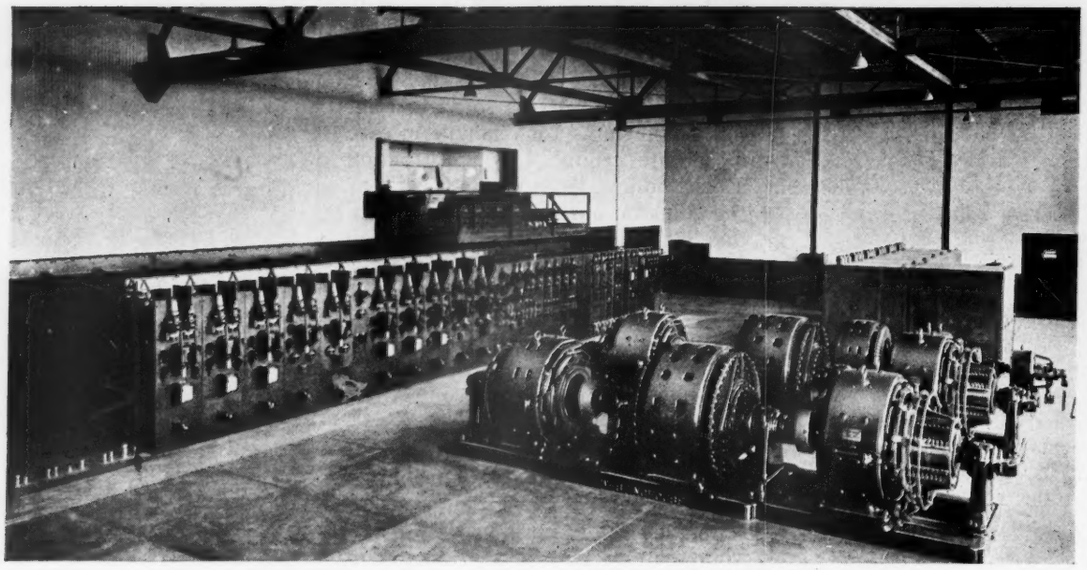


Fig. 1—An installation of truck-type, electrically operated circuit breakers for controlling the a.c. motors in a large steel mill.

Operating Advantages of

Truck-Type Switchboards

By F. M. BILLHIMER

General Engineer, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

THE ability of modern generating stations and substations to give dependable service is the result of much care in the selection of equipment best suited to the service. Furthermore, the individual pieces of equipment must be kept in first-class operating condition at all times, in order to insure continuous service. This means that the design and installation must be such as to allow ready inspection and prompt substitution of spare equipment in case that which is in service is damaged by abnormal system conditions.

Although there are many different pieces of equipment which contribute to the satisfactory performance of a generating station or a substation as a whole, it is desired at this time to describe and point out briefly the possibilities of an important item of equipment—the truck-type switchboard, several units of which are shown in Fig. 1, above. This type of switchboard usually consists of standard oil circuit breakers, relays, meters and instrument transformers mounted on a suitable structure that is fitted with wheels. This structure or truck fits into a self-supporting sheet-steel housing.

Truck-type switchboards, in general, are built for the same kinds of service as other switchboards and are designed to carry the same switching and other equipment that has heretofore ordinarily been mounted on stationary structures. These boards are made of metal, whereas the use of masonry was previously more common. Standard apparatus is used throughout on such switchboards, which in their completed form afford unusual features for safety to life and property.

Although truck-type switchboards are usually of the indoor type, their application is not limited to indoor use. For example, a truck unit for indoor service can also be used in an outdoor switchhouse that has been especially constructed with rails, disconnecting contacts and other necessary details for receiving the truck. The foundation can be arranged so that the removable unit can be rolled directly into an automobile truck and transported to the shop for repair or inspection.

The truck is equipped with contacts for conducting the main line current to and from the circuit breaker and the inclosing housing. In addition to these large contacts, which serve as disconnecting switches, other contacts of lighter construction are supplied for the metering and control circuits. Typical primary contacts are shown in Fig. 2.

Truck-type equipments are particularly adaptable for industrial plants on account of their safety features. All high-voltage parts are inclosed to protect the switchboard attendant from coming in contact with them. The framework of the housing and the truck is grounded. The equipment itself is thoroughly interlocked to prevent mistakes in operation that might cause injury to the operator.

Safety is assured the switchboard attendant, as all live, high-voltage parts are isolated and the equipment is thoroughly interlocked to prevent the circuit breaker from being inserted into or removed from the housing until the breaker is in the open position. When the circuit breaker has been removed from the housing, all high-voltage buses and contacts are automatically covered by shutters which prevent accidental contact with these parts.

The duties of maintenance and inspection may be safely carried out, as the truck containing the circuit breaker, operating mechanism, instrument transformers, meters and relays can be taken out of service, as shown in Fig. 3, by simply removing

it from the housing, thus disconnecting all parts from the circuit.

In addition to insuring safety for the attendant and providing protection and switching facilities equal to those afforded by standard, stationary circuit breakers and other equipment mounted on a structural or pipe framework or in masonry cell structures, the truck-type switchboard has a number of other inherent advantages.

For example, it provides a double set of simultaneously operated disconnecting switches interlocked with the breaker. The primary contacts isolate both sides of the breaker when the truck is withdrawn. As in the case of breakers in stationary structures, truck breaker operation may be checked when isolated from the busbars, as the secondary contacts are not opened in the disconnected or partially removed position of the truck.

Low maintenance cost is possible because repairs may be made at the time and place that are most convenient. A spare truck may be used while another truck is being inspected or repaired.

Unity of responsibility is assured with this type of equipment. This responsibility rests with the manufacturer, as he builds the equipment, assembles, tests and inspects it before shipping it to the purchaser.

Service interruptions are of short duration, as the operator can insert a spare truck should this be necessary. All trucks of like type and rating are usually made interchangeable between housings.

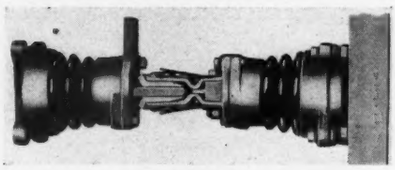


Fig. 2—Details of primary contacts used on truck-type switchboards.

The height of the building that houses the equipment can be reduced to a minimum, as there are no vertically mounted disconnecting switches, and the space required for tank removal can be eliminated if an inspection pit is used for that purpose. Floor space can also be saved, as no aisle is required behind the ordinary truck-type switchboard.

Installation cost is low, as the purchaser does not assemble and mount the various pieces of equipment. He simply places the housing at the desired location, connects the primary cables and the secondary control wiring at the proper location in the housing, and then pushes the truck into the housing. Due to this small amount of work to be performed, an extremely short period of time is required for installation.

The housing is a unit portion of the structure which is made separate from the other parts for convenience in manufacture, installation, and operation. Housings are usually occupied by fixed equipment. They may, however, be occupied by movable equipment or by a combination of fixed and movable equipment.

Housings are built of structural steel members joined by cast corner pieces—all bolted together to form extremely rugged structures which will not be distorted during shipment or when inserting or withdrawing the trucks. Sheet steel is used for covering the housings. Guide extensions are provided at the forward end of the rails to center the truck as it enters the housing. The rails are drilled for foundation bolts, and the uprights are provided with holes for bolts between adjacent housings. The sides adjacent to bus compartments are removable to allow for extensions and for the installation of the busbars. Access to busbar supports, primary contacts, cable terminals and the like is provided by removable plates.

The superstructure of a truck-type switchboard is the upper portion of the housing over the truck compartment and may be occupied by busbars, disconnecting switches, or voltage transformers.

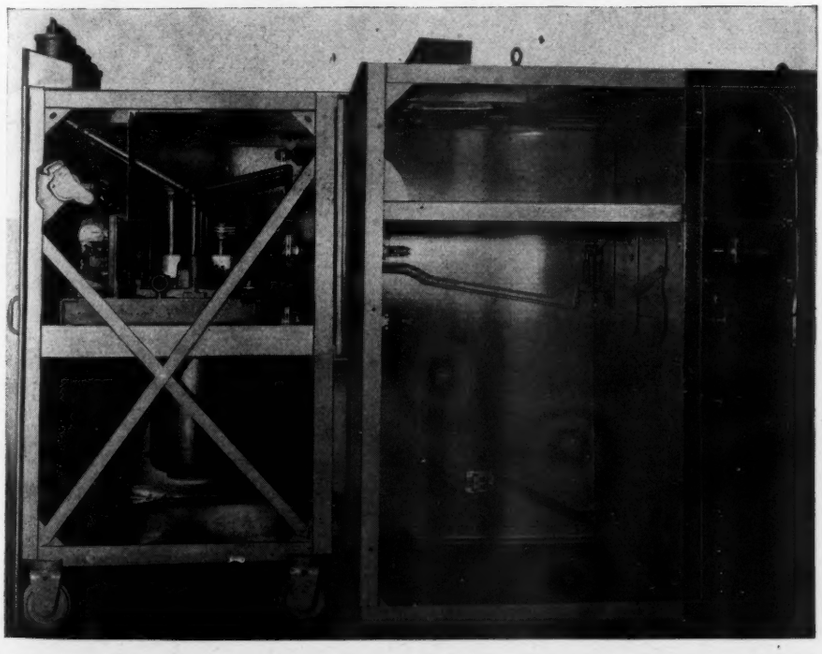
The truck is a wheel-mounted framework of the same substantial construction as is employed for the housing and carries an oil circuit breaker, instrument transformers, relays, and instruments as required. The front panel is of smooth-finished sheet steel of sufficient thickness to give a rigid surface for mounting the apparatus. The truck is equipped with contacts for conducting the power between the truck and its inclosing housing. In addition to these larger contacts, other contacts of lighter design are supplied for the metering and control circuits. The trucks are equipped with wheels running on roller bearings. Fig. 4 shows the side and rear views of a truck carrying a Westinghouse Type B-13 circuit breaker. The construction of the truck and method of mounting the contacts and other parts are clearly shown in this illustration.

Truck-type switchboards are arranged so that the truck may be withdrawn a safe distance, clear of the live contacts, and latched there. In this position the primary contacts are open, whereas the secondary contacts are closed, providing a ready means of testing the instruments and the operation of the breaker.

The secondary disconnecting devices are self-aligning and remain in

Fig. 3—Truck-type, 1200 amp. circuit breaker and housing for 6,600-volt steel mill service.

This illustration shows the housing with the sheet-iron sides removed. The truck is in the totally disconnected position. The bus insulators and stationary contacts may be seen at the right, in the rear of the automatic shutters.



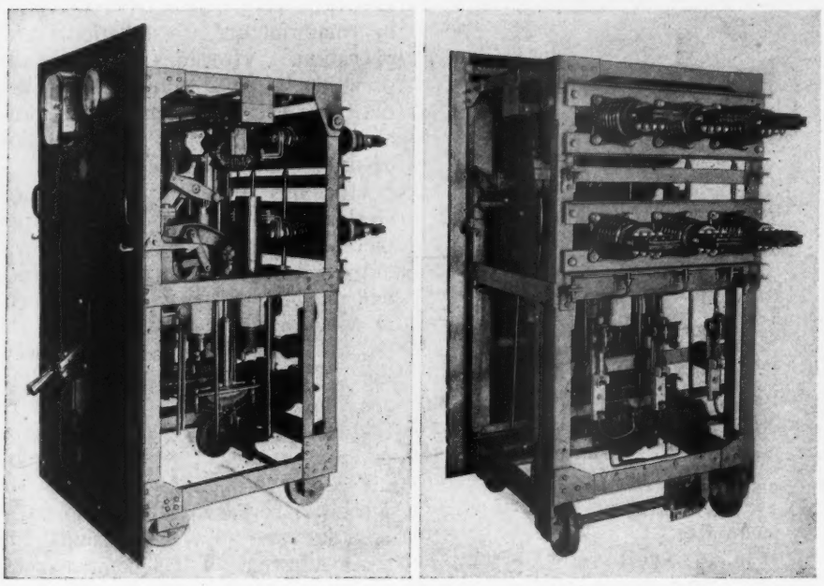


Fig. 4—Construction of the truck and method of mounting the contacts and other parts.

These are the side, at the left, and rear views of a truck carrying a Westinghouse Type B-13 circuit breaker. The contacts at the back of the truck engage with similar contacts at the rear of the housing when the truck is in the operating position.

contact when the truck is withdrawn to the disconnecting position in order that the breakers and instruments may be tested for operation while isolated from the bus. The finger board on the truck is free to move horizontally and carries a guide pin at either end which engages with a fixed guide rail in the housing. This insures that the fingers will engage centrally on the contact shoes.

Automatic shutters, shown in Figs. 3 and 5, are provided for closing the opening at the rear of the housing through which the primary contacts pass. The shutters clear the opening for the live contacts as the truck is driven into the housing and close the opening again as the truck is withdrawn, thereby keeping the live equipment inclosed and isolated. The shutters can be blocked open for inspection purposes if desired.

As generally applied, interlocks make sure that none of the disconnecting devices between the trucks and the housings can be opened when carrying current or closed to establish current flow. The principal interlocks are mechanical and operate so as to require the circuit breaker to be open when the truck is being inserted or withdrawn from the cell. Electrical interlocks may also be used in combination with the mechanical interlocks.

The truck drive provides a positive lock in the operating position so that the truck cannot be moved except by means of a levering device. This gives additional insurance against the accidental disconnecting of the truck due to internal forces.

The field of application for truck-type switchboards is large, involving many classes of service. Steel mills, municipal plants, central-station companies and many industrial plants find this form of switchboard construction to be well adapted to the needs of their service.

The cost of truck-type boards will, of course, vary with the characteristics of the equipment, such as the interrupting capacity of the circuit breakers, the number of relays, meters, and the like. The cost of the completely assembled and tested equipment, as received by the purchaser, will naturally be more than for the same equipment unassembled and untested. Installation expense varies somewhat with local labor conditions. It is, however, a rather generally accepted fact that due to the small amount of installation work and testing required for the truck-type switchboard, the total cost of equipment, installation and testing is approximately the same as for the type which is purchased unassembled. In addition, the features mentioned above as distinct advantages are secured at very little, if any, extra cost to the purchaser.

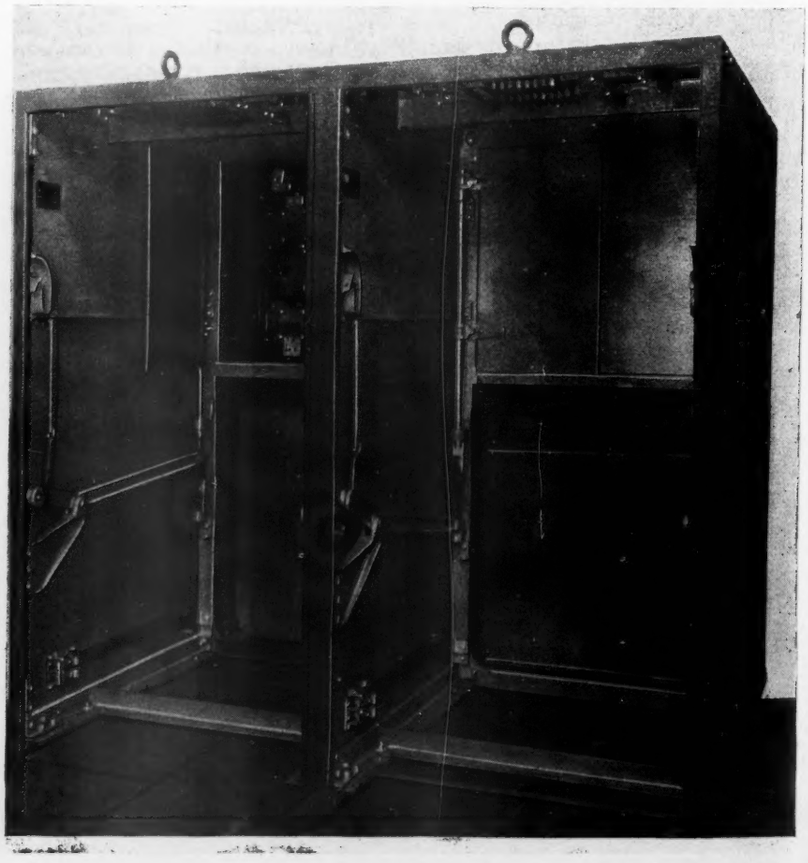


Fig. 5—Automatic shutters at the rear of the truck housing prevent accidental contact with live parts.

One cell is shown with the shutters open and one with the shutters closed. The shutter-operating mechanism can be seen on the side walls of the cells. When the truck containing the circuit breaker is pushed into the cell, the lever is raised against the action of the tension spring by a suitable engaging member on the truck. The auxiliary contacts may be seen at the top of the cells; the grounding contacts are on the side walls at the bottom.

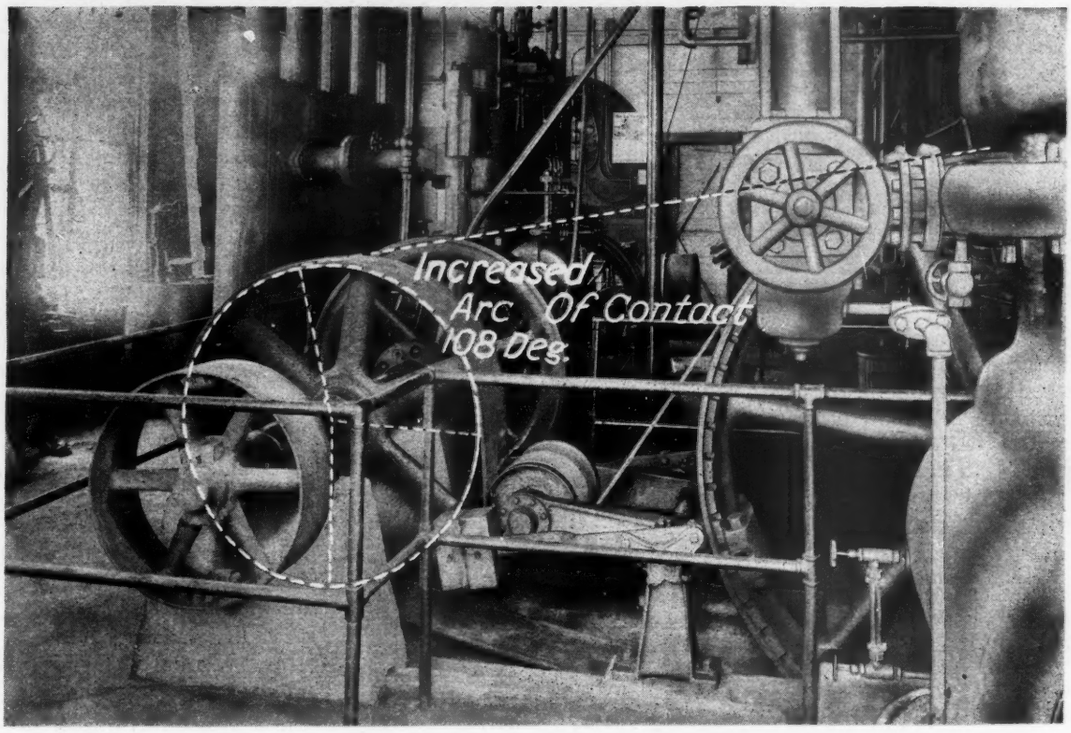


Fig. 1—Small pulleys do not have as much belt area in contact on open drives as when a flexible idler is used, as is shown by the dotted lines. This necessitates higher tension on the open drive to pull corresponding loads and as a result, a pulley approximately 25 per cent smaller can be used on flexible idler drives than would be required on open drives.

Influence of Pulley Diameter on

Power Transmitted by Leather Belt Drives

By ROY C. MOORE
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PREVIOUS articles* in this series on leather belt operating practices which have already appeared in INDUSTRIAL ENGINEER have discussed the importance of having a proper center distance on open belt drives and the use of fixed or flexible idlers where shorter center distances were desirable or necessary. Another point, which also has an important effect on belt life and operating difficulties or freedom from troubles, is the diameter of the smaller pulley.

The ratio of speed reduction in any installation is determined by the relative speeds of the driving and driven shafts. This ratio on any particular drive is usually fixed very definitely and can seldom be changed much, if any, without creating an entirely new operating condition.

Because the cost of the two pulleys increases with the diameters it is less expensive from the standpoint of installation first cost to use as small a pulley as possible on the first reduction. This is particularly important with high-speed motors because, even in ordinary drives, reductions of 6:1 or even more are quite common. This would necessitate a large pulley with a diameter six or more times as great as the smaller pulley. Thus each inch saved in the diameter of the smaller pulley has a multiple saving in the diameter and cost of the larger pulley.

There is a minimum diameter, however, below which it is inadvisable to go because of the effect of the decreased surface in contact and shortness of bend, as will be explained later in this article, on the belt as it passes around the small pulley. Before continuing further it may be well to emphasize that the rules for belt thickness as regards minimum pulley diameters are just as applicable to the idler pulley as to the driver or driven pulley, whichever is the smaller.

The lack of suitable data in any of the standard engineering handbooks on the minimum diameter of pulleys suitable for given loads has been the cause of many short-lived belts, as well as an endless amount of trans-

*NOTE—The first article of this series entitled "Factors in Determining Proper Center Distances for Leather Belt Drives," appeared in the May issue, and the second, "Fixed and Flexible Idlers on Leather Belt Drives," in the July issue.

Figs. 2*A* and 2*B*—Relation of pressure to area of contact

When only the finger tips are resting on the desk, as at *A*, very high pressure must be applied to the small area in contact to prevent slipping. However, where the whole palm of the hand rests on the desk as in *B*, less pressure is necessary to prevent slipping. Similarly, to prevent slip where a small area of belt surface is in contact with the pulley a higher tension must be maintained than with a larger area of contact or wrap.

mission troubles. A better understanding of these troubles and their underlying causes will undoubtedly result in a better appreciation of what is required of the belt and pulley and the effect of neglecting these requirements upon satisfactory operation.

One of the first considerations is that the load, which is applied through the surface friction on the belt, must be distributed over a certain amount of pulley area for satisfactory operation. When the area of contact is too small the belt must be run excessively tight to increase the friction and obtain sufficient grip on the pulley. Also, since in such cases the friction between the belt and pulley is confined to a very small area there is a constant tendency to tear the surface of the belt. The result of operating under such conditions shows up quickly in the form of checks or cracks on the belt's surface. These cracks increase in size rapidly and soon grow into decided rents which indicate that the leather fibers are gradually being torn apart.

Insufficient contact area is also responsible for another trouble—friction burning. Friction burning is caused by the belt stretching, which reduces the pressure between the belt and the pulley surface to a point where the small area in contact can no longer adhere, and excessive slipping is the consequence. The friction created by such slippage soon burns the belt's surface. This condition is first indicated by a glazed appearance, and in many cases causes actual charring of the leather, especially if such a condition is permitted to continue for any length of time. Burned belts have lost many of their necessary physical qualities, particularly elasticity, and it is impossible to restore them to good condition. A slipping belt with a good surface (coefficient over 0.5) practically always identifies itself by a squeal, but if the surface is glazed or oily it may slip quietly and be noticeable only by the heat of the pulley face.

Anyone can realize more readily the value of area contact by performing the simple experiment of sliding the palm of the hand over the desk top and then trying to secure the same grip when applying an equal pressure by using only the point of one finger or even of all the fingers. Figs. 2*A* and 2*B* illustrate this point. When trying this simple experiment notice the greater pressure required to make the finger tip or tips grip as well as the palm of the hand or, with the same pressure, note the better grip of the palm as compared to the finger or fingers.

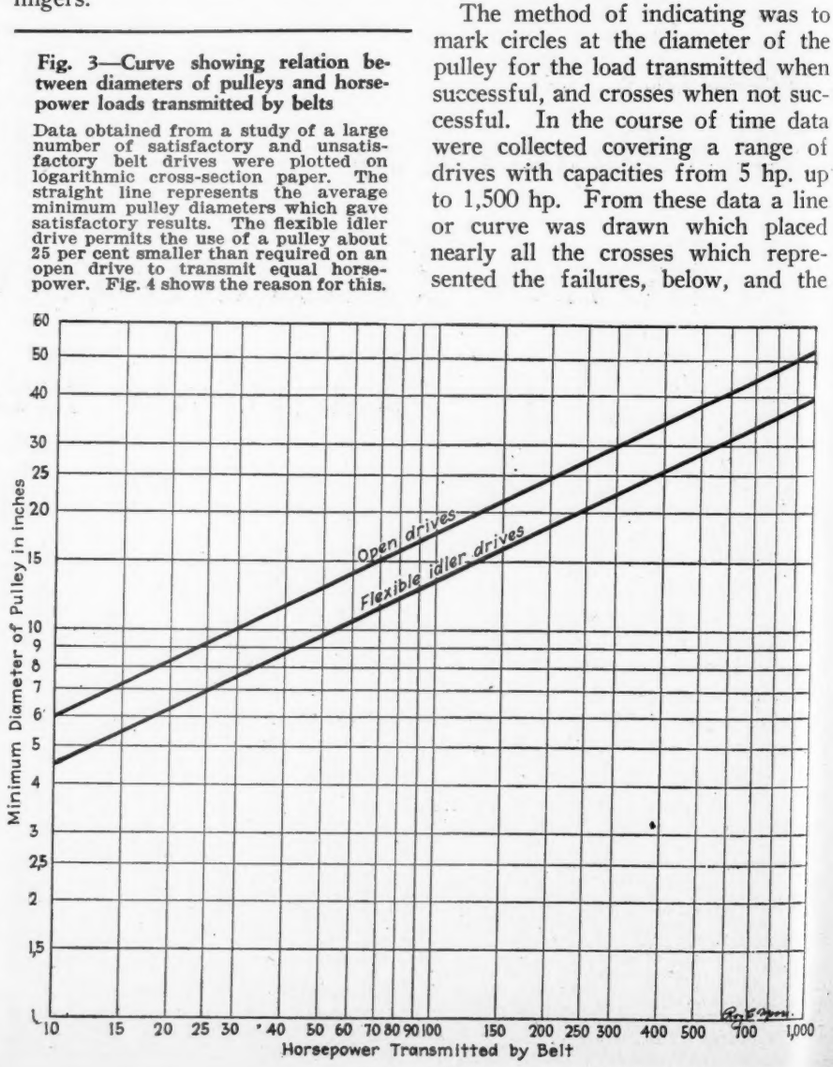
Fig. 3—Curve showing relation between diameters of pulleys and horsepower loads transmitted by belts

Data obtained from a study of a large number of satisfactory and unsatisfactory belt drives were plotted on logarithmic cross-section paper. The straight line represents the average minimum pulley diameters which gave satisfactory results. The flexible idler drive permits the use of a pulley about 25 per cent smaller than required on an open drive to transmit equal horsepower. Fig. 4 shows the reason for this.

Because comparatively little data have been published on the effect of pulley diameter on belt life it was necessary to draw on practical operating data obtained from the history of a number of belts. In compiling a list of minimum diameter pulleys suitable for various loads, records of belts giving satisfactory service over a period of years, as well as drives where belts showed early failure, were carefully analyzed. First, all those cases were discarded where certain factors in regard to the drive showed the working strain to be either below or above a normal load for the belt.

Upon analysis of the remainder it was noted that in nearly all cases the belts did not have a satisfactory life when the pulley diameter was less than a given size. The writer, when compiling the information obtained from these records, found it convenient to plot on logarithmic cross-section paper, data as collected on drives which were failures as well as those which were successful.

The method of indicating was to mark circles at the diameter of the pulley for the load transmitted when successful, and crosses when not successful. In the course of time data were collected covering a range of drives with capacities from 5 hp. up to 1,500 hp. From these data a line or curve was drawn which placed nearly all the crosses which represented the failures, below, and the



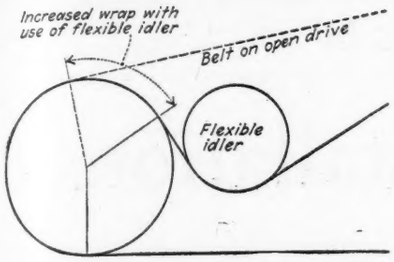


Fig. 4—This shows why a flexible idler drive will transmit more power than an open drive.

The flexible idler gives an additional belt wrap which increases the amount of belt surface in contact with the pulley. This permits the transmission of greater loads with the same size of driving pulley or the use of a smaller pulley (approximately 25 per cent smaller, as shown in Fig. 3) to transmit the same load. Any decrease in the size of the smaller pulley, as described in the text, permits a saving in first cost due to a correspondingly proportional decrease in the size of the larger pulley required to maintain the same ratio of reduction.

circles representing the satisfactory drives, above. Oddly enough, the curve, Fig. 3, proved to be a straight line when plotted on logarithmic paper.

A similar curve was plotted for the successful and unsuccessful drives using flexible idlers. (It must be appreciated that a flexible idler is not a cure-all. If the belt or pulley size is not correct or if the idler is improperly installed the drive is likely to cause as much trouble as similar improper conditions on an open drive.) When the data on the flexible idler drives were plotted it was found that the second curve, Fig. 3, was 25 per cent lower than the curve on open drives. This increased effectiveness of the smaller pulley was due to the greater wrap of the belt on the pulley as a result of using the idler. The amount of this increase in wrap is well shown by the sketch, Fig. 4. With the increase in wrap, it is not necessary to apply such a high tension or pull to get the same friction load on the larger surface. The area in contact increases in proportion to the increase in the amount of wrap.

Because of the difficulty of using the data on a curve of this sort when laying out drives the information in Table I was compiled for more ready reference. In this table fractions have been dropped and the nearest larger commercial sizes of pulleys in common use have been listed. These minimums, if religiously adhered to, will eliminate difficulties caused by pulleys that are too small for the load to be transmitted over them.

In using the pulley sizes listed in Table I, it is assumed that in each case a belt of the proper thickness and pliability will be used. It is desirable at all times when rather small pulleys are used to install the more pliable belts. Constant bending over small pulleys will soon break down the fibers in a stiff belt and shorten its life materially. A pliable belt bends much more easily and with no injury to its fibers.

It is generally conceded that oak-tanned belts (one type of vegetable tannage) are in general much longer lived than belts of special tannage. In looking over the outstanding records for long belt life, oak-tanned belts are in a large majority and practically predominate in all cases that have come to the attention of the writer. Special-tannage belts certainly have an important place in belt drives but the oak-tanned belt is usually to be preferred for general use on account of its much longer life and the fact that the total amount of stretch during its life is less.

Table I—Pulley Diameters for Horsepower Ratings

Horsepower	Minimum Diameter, Inches
10	6
20	8
30	10
40	11
50	13
75	16
100	18
150	21
200	24
250	27
300	30

NOTE—The normal ratings in the table are based on the use of pulleys no smaller in diameter than those given in the second column above. Where smaller diameter pulleys are to be used, complete operating data and a description of the drive should be submitted to the engineering department of the belt manufacturer, who will recommend the size and thickness of belt suited to the particular installation.

Although a pliable belt is usually more desirable than a stiff belt it will be found that the stiff belt is much superior on drives where the belt is subject to constant shifting because its edges will not crumple and break down so quickly as in the case of a pliable belt. Although pulley sizes are of extreme importance as regards the success or failure of the belt on the average drive, pliability and thickness of the belt are also very important factors.

The data given in Table II, which are commonly used by many belt men, may be of aid in determining whether the thickness of belt to be chosen will operate satisfactorily over the pulley. As a suggestion, it is well to give the details of any unusual drive to a belt manufacturer, and then follow his advice. This will assure the buyer of satisfactory belt operation under the conditions present in his plant.

Any departures made from the data given in Table II, such as allowing for wider pulleys and proportionately wider belts, are not to be recommended unless the plans for the drive in question are submitted to a belt manufacturer and approved by his engineering department before the belt is purchased.

The next article of this series, to appear in an early issue, will discuss the subject of belt speeds and their influence on the approximate costs of installation and operation.

Table II—Minimum Diameters of Pulleys Recommended for use with Leather Belts

Linear velocity of belt in feet per minute				1,000	2,000	3,000 and up
Width	Ply	Weight	Thickness, In.	Pulley Diameter, In.		
		Chrome	5/32	2	2½	3
Up to 8 in	Single	*Light	1/4	2	2½	3
		*Medium	5/32	3	3½	4
		*Heavy	5/16	4	5	6
		Chrome	5/16	6	7	8
Up to 12 in	Double	*Light	1/4	4	5	6
		*Medium	5/16	8	10	12
		*Heavy	3/8	10	13	14
Up to 24 in	Triple	Chrome	1/2	18	24	36
		* Heavy	9/16	24	30	36

*Oak-tanned leather belts.

Requirements and Practices in

Wiring for Motor Installations

By GORDON FOX
Electrical Engineer, Freyn Engineering Co., Chicago, Ill.

THIS is the second article of a series of two, in which Mr. Fox discusses the Code requirements and recommended practices in installing conduit work and wiring for motor installation. The first article appeared in the July issue and dealt with the considerations involved in installing the motor control and protective devices, and in meeting the starting current limitations imposed by public utilities.

THE previous article on this subject, which appeared in the July issue, covered the considerations involved in motor installation, in so far as the motor, control, protective devices and starting current limitations were concerned. This article will deal with the Code requirements and recommended practice with respect to conduit work and wiring considerations.

The proper size of wire or cable to be used in connecting a motor is dependent upon several considerations. The minimum permissible size is fixed by the National Electrical Code, the requirements of which may be summarized as follows:

Conductors carrying the current of a single motor must have carrying capacity, according to the Code tables, of at least 110 per cent of the nameplate current rating of the motor.

Motors subject to peak loads (usually these are motors of varying speed and intermittent duty ratings) will require larger fuses or higher setting of circuit breakers than other motors. Therefore, the use of larger wires or cables is advisable. The carrying capacity recommended is from 110 to 250 per cent of the motor current rating, according to the service and the time basis upon which the motor is rated. The schedule for the determination of cable sizes for motors subject to peak loads is given in Table I.

For motors having large starting current, such as squirrel-cage induction motors and self-starting synchronous motors, it is required that

Table I—Summary of Code Rules for Motor Wiring and Cutouts

Capacity of Line

SMALLEST SIZE ALLOWED: BRANCH CIRCUIT SUPPLYING ANY MOTOR MUST HAVE CARRYING CAPACITY AT LEAST 110 PER CENT OF MOTOR RATING

LARGER SIZES RECOMMENDED IN SPECIAL CASES

Motors Having Large Starting Current (Squirrel Cage, Etc.)

Started with auto-starter		Started without auto-starter
Motor Rating 0-30 Amp.	Motor Rating About 30 Amp.	
250%*	200%*	300%*

**In that portion of motor circuit not protected by motor cutout*

Motors Carrying Peak Loads

Class of Service	Percentage of Motor Rating: 5 Min Rating	10 and 15 Min Rating	30 and 60 Min. Rating	120 Min Rating	Continuous Rating
Operating valves, raising or lowering rolls	110	120	150	200	250
Rolling tables	110	120	135	180	200
Hoists, rolls, ore and coal handling machines	110	115	120	150	170
Elevators, shops, cranes, tool heads, pumps, etc.	110	110	110	120	140

Line Cutout

LARGEST SIZE ALLOWED

Motors Having Large Starting Current		Motors Not Having Large Starting Current	
Fuse (R C Wire)	Circuit Breaker	Fuse	Circuit Breaker
Value in Table II, corresponding to capacity of line	130 per cent of capacity of line	Capacity of line	130 per cent of capacity of line

Motor Cutout

WHEN REQUIRED

For Each Continuous Rated Motor of Over 2 Hp. Used for Constant-Load Duty

Having large starting current	Not having large starting current
Motor cutout may be shunted or cut out of service while starting. Figure it independently of line cutout, as below	Motor cutout must be in circuit continuously Usually make line cutout serve also as motor cutout by meeting the rule given below by using proper line capacity

For:
(1) Continuous rated motors of 2 horsepower or less; or
(2) Motors of other than continuous rating; or
(3) Motors used on other than constant-load duty

Line cutout is considered sufficient, if used

If there is no line cutout, a motor cutout is required

LARGEST SIZE ALLOWED

Fuse (or thermal cutout)	125% of motor rating, except when none of required capacity exist, then use next higher standard rating
Circuit Breaker	Time limit: 125% of motor rating Instantaneous: 160% of motor rating

the wiring between the motor cutout and the line cutout be of such size as to be protected by the line cutout. The line cutout, in turn, must be large enough to carry the motor starting current without opening. In applying this rule it is generally assumed that the starting current will be:

250 per cent of rating for motors up to 30 amp. nameplate rating when started with auto-starters.

200 per cent of rating for motors above 30 amp. nameplate rating when started with auto-starters.

300 per cent of rating for all motors started without auto-starters.

In applying this rule, the current capacity of a given size cable as shown in column *C* of Table II may be used, even with rubber-covered cable. This special rule does not apply to the wiring between the motor cutout and the motor.

Table II lists the allowable current carrying capacities of copper wire and cable with the several classes of insulation, as specified by the Code.

Although the use of solid wire is allowed, it is the author's opinion that it should never be used for motor circuits of any importance, except that sizes from No. 8 B. & S. gage to about No. 0 may be used for the connections to resistors. No cables smaller than No. 12 B. & S. gage should be used for motor connections, nor for control pilot circuits. It is preferable not to go below No. 10 B. & S. gage. These small leads should always be of stranded cable. The likelihood of delays and damage because of breakage of small solid wires is out of all proportion to the small difference in cost. Above all, solid wires should never be used for the shunt field leads of a d.c. motor or for the field leads of a synchronous motor.

The wiring for magnetic control panels often involves a considerable number of pilot circuits. Multiple-conductor cable with identifying colors or tracers is helpful in this work. A drawback to its use is the need for several cables with different numbers of conductors. It is simpler to use several single-conductor cables with different colored braids or tracers and to combine these cables as required. A consistent color scheme should be used so far as possible. Where a number of leads are run in one conduit, it is sometimes worth while to include an extra cable as a spare. This may come in handy in case of failure of one of the cables or in case a change is made in the control such as to require another pilot circuit lead. If this is not done, it is sometimes a good plan to install conduits large enough to permit of an additional lead, should such become necessary. Where many small leads are pulled in one conduit, particular care is demanded to prevent injury to the insulation while pulling.

It is essential that the voltage be maintained at the motor terminals in accordance with the nameplate rating. Usually it is not good practice for the voltage drop in the wiring of an individual motor, back to the mains or distributing point, to exceed 1 to 2 per cent of the rated voltage when full-load current flows through the circuit. Cable sizes, as determined

Table II—Allowable Carrying Capacities of Copper Wire and Cable*

Size Cable B. & S. or AWG.	Area in Circ. M.	Diameter in Mils. Bare Str. Cable	Ohms Per M. Ft.	Current Capacity in Amperes		
				Class A	B	C
				Rubber	Varnished Cambric	Slow-Burning Weatherproof
16	2,583	58	3.936	6	...	10
14	4,107	73	2.475	15	18	20
12	6,530	92	1.557	20	25	25
10	10,380	116	0.979	25	30	30
8	16,510	145	0.6158	35	40	50
6	26,250	184	0.3872	50	60	70
5	33,100	206	0.3071	55	65	80
4	41,740	231	0.2436	70	85	90
3	52,630	260	0.1931	80	95	100
2	66,370	293	0.1532	90	110	125
1	83,690	332	0.1215	100	120	150
0	105,300	373	0.0963	125	150	200
00	133,100	419	0.0764	150	180	225
000	167,800	471	0.0606	175	210	275
0,000	211,600	528	0.0480	225	270	325
	250,000	575	0.0415	250	300	350
	300,000	630	0.0346	275	330	400
	350,000	680	0.0296	300	360	450
	400,000	727	0.0259	325	390	500
	500,000	815	0.0207	400	480	600
	600,000	892	0.0173	450	540	680
	750,000	997	0.0138	525	630	800
	1,000,000	1,152	0.0104	650	780	1,000

*Specified by the National Board of Fire Underwriters.

Table III—Cable Sizes for Continuous-rated D.C. Motors

B. AND S. GAGE						10	8	6	5	4	3	2	1	0	00	000	0000
SAFE CARRYING CAPACITY—AMP.						25	33	45	53	63	75	88	100	125	150	181	218
H.P. AT 115 VOLTS	H.P. AT 230 VOLTS	H.P. AT 500 VOLTS	FULL LOAD CURRENT AMP.	110% LOAD CURRENT AMP.	125% LOAD CURRENT AMP.	DISTANCE IN FEET THAT STATED H.P. CAN BE TRANSMITTED WITH ONE VOLT LOSS. *Note: This table is based on two leads to the motor.*											
		½	1.00	1.10	1.25	490	778	1232	1560	1920	2433	3122	3940	4928	6271	8907	9971
		1	2.00	2.20	2.50	245	389	616	780	960	1216	1561	1970	2464	3135	4453	4985
	½		2.30	2.52	2.87	213	348	535	680	834	1057	1357	1713	2142	2726	3872	4335
		2	4.00	4.40	5.00	122	194	308	390	480	608	780	985	1232	1567	2226	2492
½	1		4.50	4.95	5.62	108	173	273	346	426	540	700	875	1095	1395	1975	2215
		3	6.00	6.60	7.50	81	127	205	260	320	405	520	656	821	1045	1484	1661
		4	7.50	8.25	9.37	65	104	164	208	258	328	416	525	657	836	1187	1330
1	2		9.00	9.90	11.25	54	86	137	173	213	270	347	438	547	697	990	1108
		5	9.30	10.23	11.62	53	84	132	167	206	261	335	423	530	674	947	1072
	3	7½	12.50	13.80	15.62	40	61	100	125	153	194	250	315	394	501	712	798
		10	16.50	18.10	20.62	29	47	76	96	118	147	189	239	298	380	539	604
2	4		18.00	19.80	22.50	27	43	68	86	106	135	173	219	273	348	495	524
	5		21.10	23.20	26.37	23	37	58	77	91	115	146	186	233	297	442	472
3		15	25.00	27.50	31.25	20	30	50	62	76	97	125	157	197	250	356	399
	7½		28.20	31.02	35.25		27	43	55	68	86	110	140	174	222	315	353
	10	20	33.15	36.46	41.43		23	37	47	58	76	94	119	148	189	271	300
5		25	37.60	41.36	47.00			32	41	51	64	83	104	131	164	236	265
		30	42.00	46.20	52.50			29	38	45	58	73	93	116	143	211	236
7½	15		49.70	54.67	62.12				31	39	49	64	79	99	126	179	200
		40	56.50	62.15	70.62					34	43	55	70	87	111	157	176
10	20		66.30	72.93	82.87						36	47	60	79	95	135	150
		50	75.30	82.83	94.12						32	41	52	65	82	118	132
	25		82.80	91.08	103.50							37	47	59	75	107	120
		60	94.10	103.51	117.62								41	52	66	94	106
15	30		99.40	109.34	124.25								39	49	63	89	100
		70	113.00	124.30	141.25									43	55	78	88
		80	116.00	127.60	145.00									42	54	76	85
20	40	90	132.00	145.20	176.00										47	67	74
		100	150.00	165.00	187.50										41	59	66
25	50		165.00	181.50	206.25											54	60
		120	188.00	206.80	235.00											47	53
30	60		198.00	217.80	247.50												50
			226.00	248.60	282.50												44

Table IV—Cable Sizes for Three-Phase, 220-Volt Alternating-Current Motors

Horse-power	Full Load, Amp.	110 Per Cent of Full Load, Amp.	Cable Size	125 Per Cent of Full Load, Amp.	Cable Size	Starting Current		Cable Size, Code Basis
						Per Cent Full Load, Current	Amp.	
1	3.5	3.9	14	4.4	14	250	8.7	14
3	9.5	10.5	14	11.9	14	250	23.8	10
5	15.4	16.9	12	19.3	12	250	38.6	6
7.5	22.4	24.6	10	28.0	8	250	56	4
10	29.0	31.9	8	36.3	6	250	73	3
15	42.5	46.6	6	53	5	200	85	2
20	55	60.5	4	69	4	200	110	0
25	68	74.8	3	85	2	200	136	00
30	80	88.0	2	100	1	200	160	000
40	105	115	0	131	00	200	210	0,000
50	130	143	00	163	000	200	260	30,000
75	192	211	0,000	240	250,000	200	384	500,000
100	252	278	350,000	315	400,000	200	504	750,000
150	368	405	600,000	460	700,000	200	736	1,250,000
200	484	532	750,000	605	1,000,000	200	968	2,000,000

Use column 4 for circuit from controller to motor for squirrel-cage and synchronous motor and for the entire circuit for wound-rotor motors.
Column 6 may be used for circuit ahead of controller for wound-rotor motors to permit larger line cutouts.
Use column 9 for circuit ahead of controller for squirrel-cage and self-starting synchronous motors.
Use next larger wire size throughout for motors whose speed is below 600 r.p.m.

by Code rules, should, therefore, be checked for voltage drop, particularly where the runs are at all long. With d.c. motors two or four leads must be considered, four being required with reversible, series and compound-wound motors. With three-phase a.c. motors the total drop is 1.73 times the drop in one lead.

Where conduits are buried and grouped or situated in warm locations, it is advisable to use liberal cable sizes in order to avoid temperatures which may hasten deterioration of the insulation.

Table III will be found useful for selecting cable size and checking the voltage drop of continuous-rated d.c. motors of any standard voltage. The table shows the full-load current, and the 110 and 125 per cent load currents of a range of motor sizes. These figures are based on conservative motor efficiency values and may differ slightly from actual nameplate ratings. The allowed safe capacity of various wire sizes is shown among the column headings. A wire size should be selected having a capacity of at least 110 per cent of the rated motor current. The length of circuit (two leads) which will cause 1 volt drop is shown. Greater distances cause proportionately greater voltage drop. Where four leads run to a series or compound-wound motor, the drop is double that shown. A ready check on voltage drop for any motor with any suitable cable and for any distance is easily and quickly obtained.

Table IV gives data for selecting sizes of cables for three-phase, 220-volt a.c. motors. Table V gives similar data for three-phase, 440-volt a.c. motors, and Table VI covers three-phase, 550-volt a.c. motors. The full-load current values given in column 2 are based on induction motors of moderate speed, which have fair efficiencies and rather low power factors. High-speed induction motors will have somewhat lower current ratings. Induction motors below 600 r.p.m. will have higher current ratings and will, in general, require one size larger cable. Synchronous motors operated at unity power factor will have lower current ratings, thereby permitting the use of smaller cables in some cases. These motors, however, are not always operated at unity power-factor, so a little leeway in cable size is permissible.

Cable sizes given in column 9 are based on the restriction of starting currents within the limits suggested by the Code and mentioned in a previous paragraph. Circuits connecting wound-rotor induction motors to their controllers need have but 110 per cent rated current capacity if the motor drives a steady load. A feeder circuit of 125 per cent capacity is frequently advisable between the controller and the mains to permit higher setting of the line protective devices. Column 6 is, therefore, included to show cable sizes based on 125 per cent rated current. When the motor is subjected to peak loads the entire circuit should be determined by the class and the basis of the motor rating, according to Table 1.

The Code requires that the line feeding the controller for a single motor be protected by fuses rated at the current capacity of the line (column A, Table II) or by a circuit breaker which may be set up to 130 per cent of the current rating of the line. An exception is made in the case of a line feeding a squirrel-cage induction motor or a self-starting synchronous motor in that the current capacity of the line cables is then figured on the basis of column C, Table II, thus permitting slightly higher fusing or setting of circuit breakers.

The Code requires that a switch or a circuit breaker be installed to open all the lines feeding a motor; thus a three-pole switch or breaker is required for three-phase motors and a four-pole switch or breaker is required for two-phase motors. This switch or breaker must always be installed when an auto-starter or oil-immersed starting device is used, due to the oil hazard. With other types

Table V—Cable Sizes for Three-Phase, 440-Volt Alternating-Current Motors

Horse-power	Full Load, Amp.	110 Per Cent of Full Load, Amp.	Cable Size	125 Per Cent of Full Load, Amp.	Cable Size	Starting Current		Cable Size, Code Basis
						Per Cent Full Load Current	Current, Amp.	
1	1.8	2.0	14	2.3	14	250	4.5	14
3	4.8	5.3	14	6.0	14	250	12.0	14
5	7.8	8.6	14	9.8	14	250	19.5	12
7.5	11	12.1	14	13.8	14	250	27.5	8
10	15	16.5	12	18.8	12	250	37.5	6
15	21	23	10	26	8	250	52	5
20	27	30	8	34	6	250	68	4
25	34	38	6	43	6	200	68	4
30	40	44	6	50	6	200	80	3
40	52	57	4	65	4	200	104	0
50	65	72	3	82	2	200	130	00
75	96	105	0	120	0	200	192	0,000
100	126	139	00	158	000	200	252	250,000
150	184	202	0,000	230	30,000	200	368	500,000
200	242	266	300,000	302	350,000	200	484	700,000

Use Column 4 for circuit from controller to motor for squirrel-cage and synchronous motor and for the entire circuit for wound-rotor motors.
Column 6 may be used for circuit ahead of controller for wound-rotor motors to permit larger line cutouts.
Use Column 9 for circuit ahead of controller for squirrel-cage and self-starting synchronous motors.
Use next larger wire size throughout for motors whose speed is below 600 r.p.m.

of starting equipment the Code permits that the switch or circuit breaker may be omitted if the motor controller, with its overload device, disconnects all lines.

It is the best and safest practice, however, always to install a switch or circuit breaker ahead of a controller or starting device, thereby providing a safe and ready means of isolating the starting device for adjustment and repairs. If a motor cutout is required and is not otherwise provided, this switch should be fused. If motor protection is otherwise provided (of a type disconnecting all lines), the switch should not be fused. If a motor cutout is not required, the use of fuses at this point is optional.

The Code requires that all continuous-rated motors above 2 hp. used for constant-load duty be provided with motor cutouts. A motor cutout may take the form of fuses disconnecting all lines, in which case the fuses may be as large as 125 per cent motor current rating or the nearest larger size thereto. The motor cutout may take the form of an instantaneous-trip circuit breaker or instant-trip overload relays in connection with contactors disconnecting all lines. In this event the highest permissible setting is 160 per cent of the motor current rating. If the motor cutout takes the form of a time-element circuit breaker or time-element overload relays and contactors, the highest permissible setting is 125 per cent of the motor current rating.

Thermal relays alone, acting in conjunction with line contactors, do not afford complete overload protection and cannot serve as motor cutouts. In case of a short circuit or a ground these relays do not function instantly, but permit sufficient time delay to lead to damage. Frequently the thermal relay itself is damaged if the circuit is not promptly cleared.

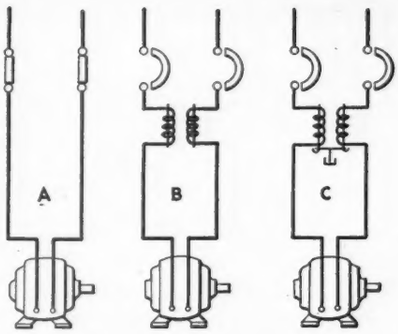


Fig. 1—This diagram shows the correct rating for fuses and setting of circuit breakers for the protection of 100-amp., continuous-rated motors.

The maximum rating of fuses in *A* is 125 amp. The circuits in *B* and *C* must carry 110 amp. continuously; therefore, the instantaneous circuit breaker in *B* must not be set over 160 amp., and the time-element circuit breaker in *C* not over 125 amp.

The Code does not require a motor cutout for motors having intermittent ratings or motors having peak load duty, for the reason that the line cutout is considered sufficient for the purpose. If the starters or controllers are grouped at a distribution point, however, feed lines and line cutouts are commonly omitted, in which case the motor cutouts are necessary.

It should be noted that with continuous-rated, constant-duty motors, a circuit of 110 per cent motor current rating is required between the motor and the motor cutout, yet it is permissible to fuse or set this cutout for 125 per cent of motor current rating. If a line cutout is used to protect the line between the motor cutouts and the mains this line must be protected on the basis of its rated current capacity. If this line represented 110 per cent motor rating, smaller fuses or a lower setting would be required for the line cutout than for the motor cutout, whereas the opposite condition is desirable. To avoid this situation, it is necessary to increase the size of the circuit between the mains and the motor cutout to permit the use of larger fuses or a higher setting. Thus, this circuit should be of at least 125 per cent of the rated motor current capacity.

The Code requirements both as to cable sizes and line and motor protection have been summarized and shown in abbreviated tabular form in Table I. Figs. 1, 2, 3 and 4 have been included in order to show typical examples of motor and circuit protection and wiring according to Code regulations.

Table VI—Cable Sizes for Three-Phase, 550-Volt Alternating-Current Motors

Horsepower	Full Load, Amp.	110 Per Cent of Full Load, Amp.	Cable Size	125 Per Cent of Full Load, Amp.	Cable Size	Starting Current		Cable Size, Code Basis
						Per Cent Full Load, Current	Current, Amp.	
1	1.5	1.7	14	1.9	14	250	3.7	14
3	3.9	4.3	14	4.9	14	250	9.8	14
5	6.3	6.9	14	7.9	14	250	15.8	12
7.5	8.8	9.7	14	11	14	250	22.0	10
10	12	13.2	14	15	14	250	30	8
15	17	18.7	12	21	10	250	43	6
20	22	24	10	27.5	8	250	55	5
25	27	30	8	34	8	250	68	4
30	32	35	8	40	6	250	80	3
40	42	46	6	53	5	200	84	2
50	52	57	4	65	4	200	104	0
75	77	85	2	96	1	200	154	000
100	100	110	0	125	0	200	200	0,000
150	147	162	000	184	0,000	200	294	350,000
200	193	212	0,000	242	250,000	200	386	500,000

Use column 4 for circuit from controller to motor for squirrel-cage and synchronous motor and for the entire circuit for wound-rotor motors.
Column 6 may be used for circuit ahead of controller for wound-rotor motors to permit larger line cutouts.
Use column 9 for circuit ahead of controller for squirrel-cage and self-starting synchronous motors.
Use next larger wire size throughout for motors whose speed is below 600 r.p.m.

Table VII—Recommended Practice for Motor Wiring

Type of Motor and Service	Cable Capacity in Per Cent of Rated Motor Current	
	Ahead of Controller	From Controller to Motor
Direct-Current Motors:		
Shunt or compound-wound—constant load	125	110
Series or compound-wound—peak load	*	*
Alternating-Current Motors:		
Small single-phase types—constant load	125	110
Squirrel-Cage and Self-Starting Synchronous types, with Reduced Voltage Starting:		
0-30 amp. motor rating	250	110
Above 30 amp. rating	200	...
With full voltage starting	300	110
Wound-Rotor Induction Types:		
Constant load	125	110
Peak loads	*	*

* 110 to 250 per cent motor rating as shown in Table I.
All cable capacities refer to column *A*, Table II, if rubber-covered cable is used and to column *B*, if varnished cambric insulation is used.

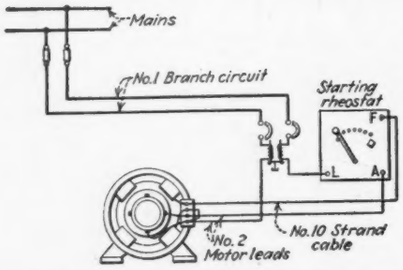


Fig. 2—Elementary layout showing the correct wiring (Code regulations) for a 20-hp., 230-volt, continuous-rated, 75.3-amp., d.c. shunt motor.

An 85-amp. capacity time-circuit breaker with a setting not to exceed 95 amp. is specified, with line cutouts fused for 100 amp.

In the above discussion, Code rulings and recommendations have been set forth. These represent a minimum standard of safe practice. They do not necessarily guarantee a satisfactory installation in all cases. Their complexity is inimical to their general and proper application. In an endeavor to combine both Code requirements and desirable practices in as simple a summary as possible, Table VII has been prepared by the writer, setting forth the minimum cable sizes recommended for motor installations. These sizes must be checked for voltage drop wherever runs of any length are involved.

The recommended practices for motor wiring as indicated in Table VII are based upon the thought that the branch cables ahead of controllers should be large enough to permit the cutout at the feed end of the branch circuit to be set at least as high as is permissible for the motor cutout. The writer considers that the proper place for motor protection is at the motor controller and not at some remote point, such as the source of the branch circuit feeding the controller. In fact, it is often desirable to eliminate, so far as possible, such branch circuits feeding individual motors, either by combining several motors on one branch circuit or by grouping the controllers at the distribution point and eliminating branch circuits altogether.

Although Table VII differentiates between the cable sizes ahead of the controller and between the controller and the motor, it is frequently more practicable to use the larger size of cable throughout. Likewise, it is hardly necessary for an industrial plant to stock and use every size of cable. Some sizes may well be omitted from the list, and the next larger size substituted. The saving in inventory and handling through standardization will offset the higher cost and some benefit will accrue through the occasional use of oversize cable.

A matter of considerable importance, however, is the location of conduits with respect to the equipment involved. They should never be run above or in close proximity to furnaces, flues, and hot pipes for the same reason that open wiring would be considered dangerous in a like installation. Conduits which are buried underground permit of little heat radiation; so when wiring is to pass through underground conduits wire sizes as well as conduit sizes should be liberal. Metal conduits carrying heavy currents, particularly when buried, should be somewhat isolated from each other, for if grouped together too closely hot spots may result, leading to rapid deterioration of the insulation and subsequent failure to the installation.

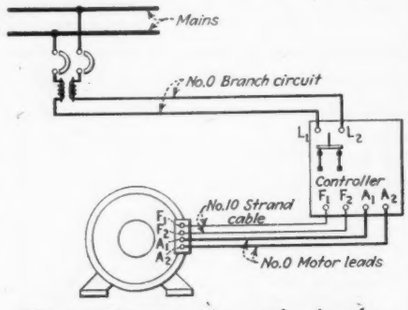


Fig. 3—Elementary layout showing the correct wiring (Code regulations) for a 20-hp., (120-min. rating) 230-volt, intermittent-rated, 75.3-amp., d.c. hoist motor.

No additional overload protection is required with the motor switch other than the 85-amp. capacity circuit breaker whose setting must not exceed 162 amp.

The sizes of conduits used naturally depend upon the cable to be contained. In wiring small d.c. motors, all wires may just as well be pulled in one conduit, but with larger d.c. motors it is advisable to run the shunt field leads in separate conduits because small cables are likely to be damaged when pulled in combination with large cables. Control pilot circuit wiring should not be mixed with motor wiring if this can be avoided. It is advisable to install very large cables in individual conduits, as conduit above 2 in. is difficult to work and a group of large cables may be hard to pull. Alternating-current leads must be so combined that all phases of one circuit are in one conduit. If this is not done currents may be induced in the conduit, causing it to heat. It should not be attempted to pull cable around more than four bends at the most in conduit of 2 in. or larger and this number is high if the runs are long or the cables heavy; where four bends are imperative a larger-sized conduit should be used.

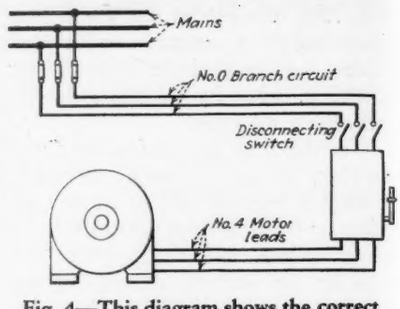


Fig. 4—This diagram shows the correct wiring (Code regulations) for a 40-hp., 440-volt, three-phase, 52-amp., continuous-rated, squirrel-cage induction motor with an auto starter.

The auto-starter overload trips are set at 63 amp. The line cutouts are fused for 200 amp.

Many motors are now provided with terminal fittings to which conduits may be directly attached; where the motor is mounted on a sliding base a short length of flexible conduit should be interposed. Open ends of conduits at motors in exposed locations should preferably terminate in

Table VIII—Conduit Sizes for Duplicate Cables 440-Volt Alternating-Current Motors

Size Cable B. & S. or AWG. Number of cables...	Size of Standard Conduit in Inches								
	1	2	3	4	5	6	7	8	9
14	¾	¾	¾	¾	1	1	1	1	1¼
12	¾	¾	¾	¾	1	1	1¼	1¼	1¼
10	¾	¾	1	1	1	1¼	1¼	1¼	1¼
8	¾	1	1¼	1¼	1¼	1¼	1¼	1½	1½
6	¾	1	1¼	1¼	1½	1½	1½	2	2
5	¾	1¼	1¼	1¼	1½	2	2	2	2½
4	¾	1¼	1¼	1½	1½	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1½	1½	2	2	2½	2½	2½	3
1	1	1½	2	2	2½	2½	3	3	3
0	1	2	2	2	2½	3	3	3	3½
000	1¼	2	2½	2½	3	3	3½	3½	3½
0,000	1¼	2	2½	3	3	3½	3½	3½	.....
250,000	1½	2½	2½	3	.....	.....	.....	.....	.....
300,000	1½	2½	3	3	.....	.....	.....	.....	.....
350,000	1½	3	3	3½	.....	.....	.....	.....	.....
500,000	1½	3	3	3½	.....	.....	.....	.....	.....

some form of fitting "looking down" so that dirt and moisture will not enter.

Sizes of conduits for various numbers of cables of one size are shown in Table VIII. These refer to ordinary cables for working pressures of 600 volts or less; however, for cables having extra insulation Fig. 5, based on the outside diameter of the cable, may be used.

Where a number of cables of different sizes are to be installed in one conduit Table IX may be used. This is based on the conduit area available as compared with that occupied by the cables. An example is given to show the application with R.C.D.B. 600-volt insulated wires.

Rubber-covered wire and cable are used in nearly all wiring for motor connections that are run in conduit. There are many grades of rubber insulation, but the new Code wire or cables are a minimum acceptable quality. The insulation on new Code wire and cable is made from rubber compounds with a minimum of fresh rubber. The fact that new Code wire and cable are passed by the National Board of Fire Underwriters does not signify that they are suitable for all uses. Where service conditions are at all severe or where reliability is of first importance it is recommended that wire and cable be specified to have not less than 30 per cent of Para rubber insulation, or that one of the higher-grade brands of rubber-covered wire or cable be used. The better quality material is somewhat more costly, but its use is fully warranted in many instances.

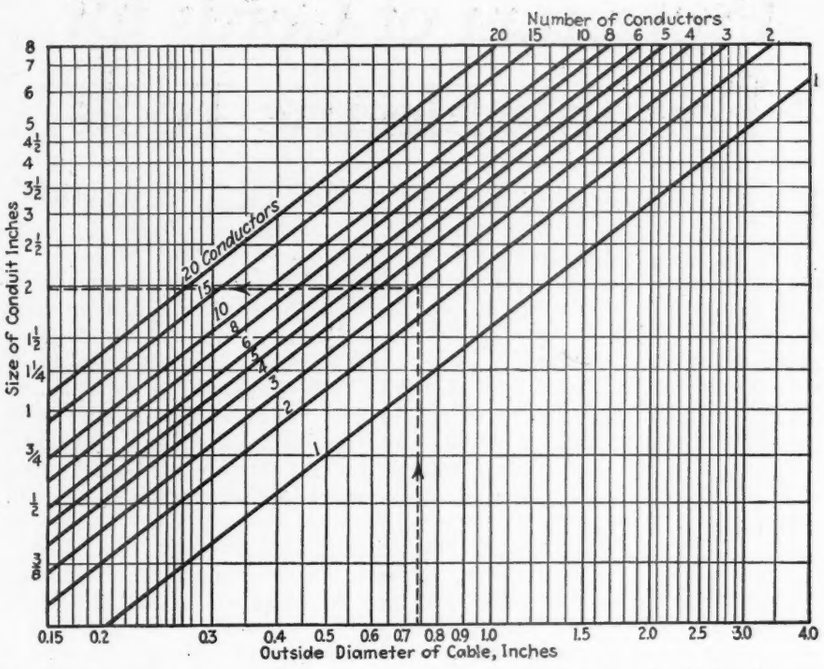


Fig. 5—Conduit sizes for high-voltage cables may be determined by means of this chart.

The conduit size is determined by tracing vertically from the line indicating the outside diameter of the cable in inches to the diagonal lines representing the number of conductors, and then horizontally to the conduit size on the left. An example is shown by the dotted line.

The Code requires multiple-conductor lead-sheathed cable in conduit for wiring of motors above 550 volts, except in power houses or substations.

Rubber insulation deteriorates, particularly at the higher temperatures. The maximum temperature allowable by the A.I.E.E. rating to avoid excessive depreciation is 50 deg. C., whereas varnished cambric insulation has the advantage in that it does not deteriorate so rapidly; consequently, a temperature of 75 deg. C. is permitted. Therefore, it is permissible to work this cable a little harder (voltage drop not considered) and it is better adapted for warm locations. Its use is not permitted for cables smaller than No. 6 B. & S. gage when subject to bending. "Slow-burning" insulation consisting of braids impregnated with flame-proof compound will sucessfully withstand still higher temperatures and is, therefore, given a higher current rating in the Code, but this insulation does not resist moisture successfully and is adapted for dry, hot locations only.

Table IX—Conduit Sizes for Different Sized Cables

SIZE OF CABLE B. & S. GAGE	CABLE SIZE, INCHES*	NO. OF CONDUCTORS FOR WIRE AREA													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	.250	.049	.098	.147	.196	.245	.294	.343	.392	.441	.490	.539	.588	.637	.686
12	.281	.062	.124	.186	.248	.350	.372	.434	.496	.558	.620	.682	.744	.816	.868
10	.312	.077	.154	.231	.308	.385	.462	.539	.616	.693	.770	.847	.924	1.001	1.078
8	.344	.093	.186	.279	.372	.465	.558	.651	.744	.837	.930	1.028	1.116	1.119	1.132
6	.437	.150	.300	.450	.600	.750	.900	1.050	1.200	1.350	1.500	1.650	1.800	1.950	2.100
5	.469	.173	.346	.519	.692	.865	1.038	1.211	1.384	1.557	1.730	1.903	2.076	2.249	2.422
4	.500	.196	.392	.588	.784	.980	1.056	1.372	1.568	1.764	1.960	2.156	2.352	2.548	2.744
3	.531	.222	.444	.666	.888	1.110	1.332	1.554	1.776	1.998	2.220	2.442	2.664	2.886	3.108
2	.594	.277	.554	.831	1.108	1.385	1.662	1.939	2.216	2.493	2.770	3.047	3.324	3.601	3.878
1	.656	.338	.676	1.014	1.352	1.690	2.028	2.366	2.704	3.042	3.380	3.718	4.056	4.394	4.732
0	.719	.406	.812	1.218	1.624	2.030	2.436	2.842	3.248	3.654	4.060	4.466	4.872	5.278	5.684
00	.750	.442	.884	1.326	1.768	2.210	2.652	3.094	3.436	3.978	4.420	4.862	5.304	5.746	6.188
000	.812	.518	1.036	1.554	2.072	2.590	3.108	3.626	4.144	4.662	5.180	5.698	6.216	6.734	7.252
0000	.875	.601	1.202	1.803	2.404	3.005	3.606	4.207	4.808	5.409	6.010	6.611	7.212	7.813	8.414
200,000	.906	.645	1.290	1.935	2.580	3.225	3.870	4.515	5.160	5.805	6.450	7.095	7.740	8.385	9.030
250,000	.937	.690	1.380	2.070	2.760	3.450	4.140	4.830	5.520	6.210	6.900	7.590	8.280	8.970	9.660
300,000	1.000	.785	1.570	2.355	3.140	3.925	4.710	5.495	6.280	7.065	7.850	8.635	9.420	10.20	10.99
350,000	1.062	.887	1.774	2.661	3.548	4.435	5.322	6.209	7.096	7.983	8.870	9.757	10.64	11.53	12.42
400,000	1.094	.950	1.900	2.850	3.800	4.750	5.400	6.650	7.600	8.550	9.500	10.45	11.40	12.35	13.30
450,000	1.156	1.049	2.098	3.147	4.196	5.240	6.414	7.343	8.392	9.441	10.49	11.54	12.59	13.64	14.69
500,000	1.187	1.107	2.214	3.321	4.428	5.535	6.642	7.749	8.856	9.963	11.07	12.18	13.28	14.39	15.50
750,000	1.375	1.485	2.970	4.455	5.940	7.425	8.910	10.39	11.85	13.36	14.85	16.33	17.87	19.30	20.79
1,000,000	1.531	1.770	3.540	5.310	7.080	8.870	10.62	12.39	14.16	15.93	17.70	19.47	21.24	23.01	24.78

*Outside diameter of R. C. D. B. 600-volt insulated cables.

Area of Conduit Sq.In.	Size of Conduit In.
.196	¾
.307	1
.532	1¼
.862	1½
1.485	2
2.040	2½
3.341	3
4.784	3½
7.366	4
12.588	5
16.209	6

EXAMPLE:

What size of conduit is required for 6 No. 8 and 6 No. 2 cables?
Area of 6 No. 8=0.558 sq.in.
Area of 6 No. 2=1.662 sq.in.
Total Area=2.220 sq.in.
12 cables should give an area no greater than 37% of the area of the conduit.
Area of above 12 cables=2.220 sq.in. which divided by 0.37 gives the area of conduit required.
2.22÷0.37=6 sq.in.
6 sq.in.=3 in. standard conduit.

No. of Conduit	Per Cent of Inside Conduit Area
1	.56
2	.32
3	.42
4	.40
5 and over	.37

Protection of Cords for Portable Electric Tools

By FRANCIS A. WESTBROOK
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USE of portable electric tools is increasing so rapidly and is becoming so important a factor in many industrial operations that anything which tends to influence their efficiency in one way or another is of great importance. Probably no one factor has so great a bearing on this question as the flexible electrical conductors, or "cords," which supply these tools with power. Not only is the actual make-up or construction of the cord of importance, but other details such as the manner in which the conductors are terminated at the tool, how they are supported to keep them out of the way of the operator, and so on, may determine the usefulness of the tool.

For instance, if the cord of an electric industrial iron is continually burning off where it is attached to the iron, or if it is always in the wrong place, so that it impedes the operator and lessens his production, it may be more economical to forego the obvious advantages of electric heating and go back to the old-fashioned, gas-heated irons. In other words, the cord used on a portable electric tool is absolutely essential, but if it is not of the proper kind and properly installed, it may seriously lessen the value of a useful tool.

Before going further into the subject, it may be well to say that there are now two general classes of cords on the market: those with an outside covering consisting of a braid, and those having a bare rubber jacket. The former are, as a general rule, cheaper in first cost than the latter, but it should be clearly borne in mind that savings in first cost are no more a guide as to what will prove to be the most economical in the long run in this connection than in any other engineering relationship. Obviously, it is poor economy to permit interruptions in the service of portable machines, involving also the cost of patching or changing cheap cords, when an expenditure of a few cents more per foot would very greatly reduce such losses.

Braided cords that are not capable of withstanding as much mechanical wear and tear as rubber-sheathed cords should, therefore, be used only where the service conditions are not severe.

In order to find out how different industrial users of portable tools have overcome troubles with their cords, an investigation was made in a considerable number of plants, covering a variety of conditions where such tools are being successfully used.

The hat factory of Crofut & Knapp at South Norwalk, Conn., uses about 500 electric irons. The majority are of a very heavy and rugged type with the cord permanently attached to mica-insulated terminals protected by a movable cap. In addition, some irons of the domestic type are used, which furnish a very interesting basis of comparison. Most of the trouble experienced is due to the conductors breaking at the terminals.

The type of cord used for this service has two No. 18 A.W.G. stranded conductors covered with a cotton wrapping, rubber insulation and asbestos braid, with an outer covering of cotton braid over both conductors. The conductors are skinned and rewrapped with asbestos cord up to the point where they are attached to the terminals on the iron. Tape is not used at all. It has been found that the asbestos cord, being stiff, easy to apply and fireproof, is more satisfactory than the tape that was formerly employed. Its use has reduced failures to a marked extent. There is no other protection or mechanical strengthening at the iron, except that the cord passes through a spiral spring about 5 in. long, as shown in Fig. 1.

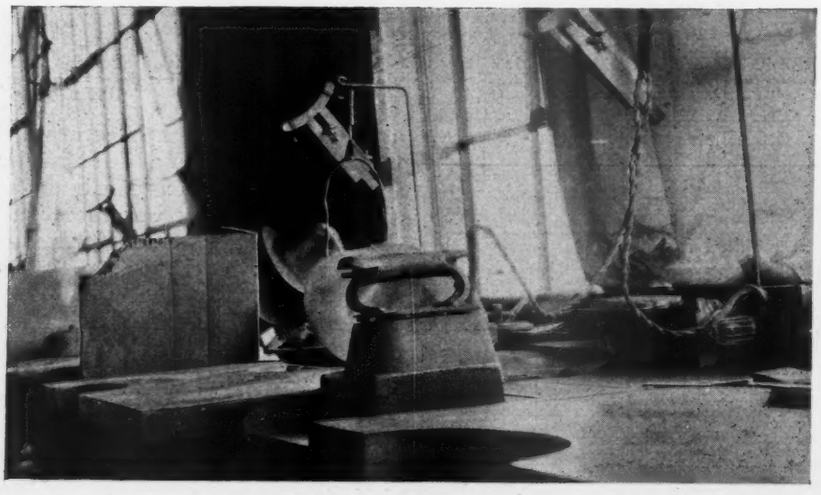

Fig. 1—Cords for heavy irons are supported by a spiral spring to keep them out of the way.

The cord is suspended from the spring by a loop of soft leather, and is protected against sharp bends at the iron by a stiff spiral spring about 5 in. long that encircles the cord. A pilot light on the outlet box at the extreme right tells the operator whether the current is on or off.

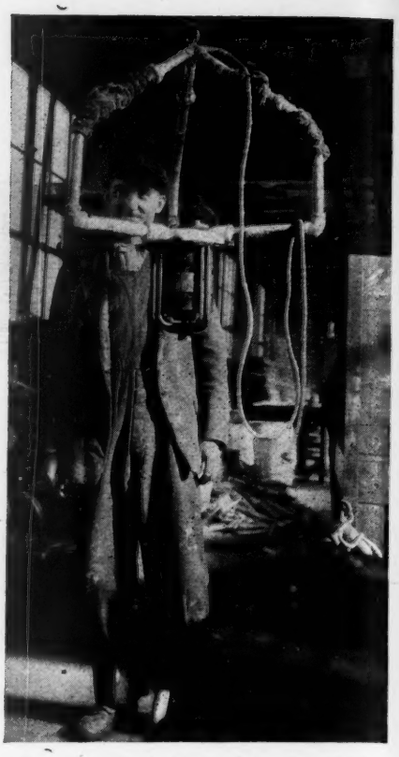

Fig. 2—The cord through which power is supplied to this "vibrator" is subjected to unusually hard service.

This device is used in the straining process during the manufacture of paint. In addition to the wear and tear incidental to being moved from place to place, the cord is frequently splashed with paint, oils and other liquids.

Two other means of protecting the cord are employed. One is a soft leather loop attached to a rather long but very resilient spring that can be drawn out to several times its original length by slight tension. The cord passes through this leather loop and as the operator works his iron back and forth this spring keeps the cord out of the way of his work. This arrangement, shown in Fig. 1, has greatly reduced burns, tending to shorten the life of the cords.

The other means of prolonging the life of cords is to clamp them at the outlet boxes close to the plug. These plugs also have red pilot lights to inform the operator when the heat is on. Switches are provided at the outlet boxes for turning the current on and off.

When new, the cords are 6 ft. long, and when they have been repaired so often that their length has been reduced to about 4½ ft., they are replaced, as by that time there are usually so many burns and the braid has become so much frayed that it is not worth repairing or saving for other purposes. The practice of splicing short lengths together and repairing a break near the middle has been given up, as it has been found that splices are certain to be weak spots that cannot last long, at best. With the present method, a cord needs attention about once a month, which does not seem excessive when it is considered that they are in constant use all day.

As mentioned before, a good many domestic irons are in use. The cord is attached to the plug for the outlet by making a half turn around the terminal. This provides adequate mechanical strength and seems to be preferable to making a knot in the cord, which strains the insulation and is likely to cause cracking and ultimate failure.

Likewise, in the manufacture of paints, a portable tool known as a "vibrator," shown in Fig. 2, is used in the straining process. This tool is moved about from place to place, and as the motor is small, the power is obtained by plugging into any convenient lighting outlet. The cord is not subjected to any severe mechanical abuse, because it practically never rests on the floor. It is, however, subjected to other seriously deteriorating influences. In the first place, the cord is continually splashed with paint, oil and volatile driers. Although this might be expected to have a deleterious effect on the rubber insulation, it has been found that a cord with a heavy outside rubber jacket and no braid gives no trouble. Nor is there any trouble worth mentioning at the plug end of the cord; but a great deal of trouble was formerly experienced at the motor end. This was because the wires had to be brought into the motor terminals through a bearing stud on the motor. The stud was formerly prevented from turning by setscrews, which frequently sheared off, thus permitting the stud to turn and cut off the wires. This happened so often that an ingenious machinist, employed in one large paint factory, made a new stud with square corners and projecting lugs, so that it could not turn, and the trouble from cut wires disappeared. A serving of several thicknesses of ordinary rubber-filled tape is applied to the outside of the cord where it passes into the opening of the machine to prevent wear.

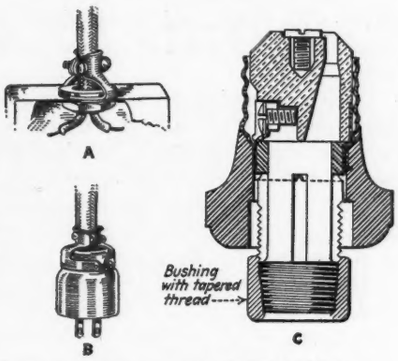

Fig. 3—The cord is firmly held by a clamping device as it enters these fixtures.

A shows an outlet box attachment manufactured by the Arrow Electric Co. The cap with a cord clamp shown in *B* is made by the Bryant Electric Co. *C* shows the details of a heavy-duty plug made by the Benjamin Electric Co. As will be seen, the bushing has a sharply tapered thread and screws over a fiber sleeve. When the bushing is tightened the fiber sleeve contracts and grips the cord.

A good many portable electrical tools are also used at the works of the Terry Steam Turbine Co., Hartford, Conn. These consist mainly of drills and grinders, and the cords are subjected to very hard usage. Heavy castings are dropped on them; they come in contact with hot steam pipes; and they lie around in the dirt and oil which accumulate on the floor. Various schemes have been tried out in this plant to reduce cord failures to a minimum, but it has been found next to impossible to make a workman give the cords any special consideration. It is also impossible, under the conditions, to take any measures to keep the cords off the floor.

Adoption of a rubber sheathed cord in place of the reinforced braided cord, formerly used, resulted in a marked improvement.

In the building trades, where many portable tools are used by electricians and others, much the same service conditions obtain as in the industrial plants just described. Here, also, the same remedies for cord troubles are applied. Cords with rubber sheathing are widely used and various devices employed to relieve strain and sharpness of bending have done much to reduce the frequency of failures.

Even in ordinary building maintenance, the problem of the best type of cord to use, and how to protect it, cannot be ignored. One example of severe service is found in the case of a stone or composition floor polishing machine, such as shown in Fig. 4. The service end of the cord is usually plugged into a baseboard outlet and lies around in the mud and moisture where the polishing is under way. It is also likely to be walked on and otherwise abused. Plainly, trouble from failures can be reduced only by

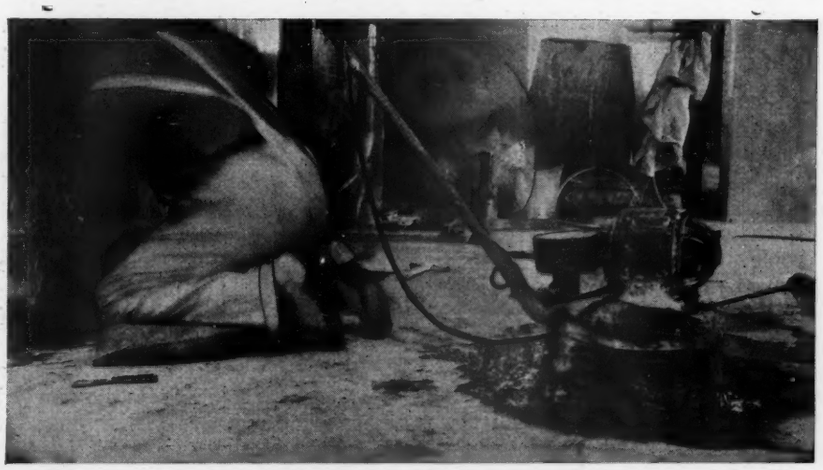

Fig. 4—The cord on this floor polishing machine is subjected to severe mechanical abuse, as well as exposure to dirt and moisture.

the use of a strong, rugged cord that is adapted to the conditions under which it is used.

A good many different makes of portable electric tools are, of course, in use and some of them are now being provided with more or less suitable means for attaching the cords. In some instances there are plug attachments on the tool, and in others the flexible cord is permanently attached to the tool and is removable only at the service outlet. The latter arrangement has the disadvantage that when the cord fails, the whole tool is out of commission. On the other hand, if there is a plug attachment at the tool it is a simple matter to have a few spare cords on hand, fitted with plugs, and to substitute a new cord when the one in use gives out.

It is interesting to note that the manufacturers of wiring devices, as well as users, have tried to eliminate some of the abuses of flexible cords. There are now various devices on the market for taking up the mechanical strain. For instance, everyone is familiar with the small fiber cleats used for the cords on telephone instruments and which, in fact, are used at times for cords such as those we are considering. Furthermore, various manufacturers make plugs and sockets with devices for securely gripping the cords as they enter. Three typical devices are shown in Fig. 3.

Contributing Causes Of Industrial Accidents

By G. E. KIMBALL
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EXPERIENCE obtained in nearly ten years of electrical inspection work with the California Electrical Safety Orders, which require safe electrical installations in places of employment, has very clearly brought out the fact that electrical installations must be made as nearly foolproof as possible. If electrical equipment is installed in a manner that will permit of its safe use by persons who are too busy with their work to give thought to the possibility of injury, the equipment will have been made reasonably safe for those who are ignorant of its dangers.

The old saying that it is a hard task to educate the public is fully corroborated by the long lists of automobile accidents that are published in our daily papers, despite the vigorous educational campaigns which are being carried on by hundreds of agencies. Innumerable ordinances have unquestionably helped thinking people, but one moment of thoughtlessness may offset years of careful conduct.

Educating workmen along the lines of accident prevention in shops, mills and factories is no less difficult. Electrical installations in such places cause but few accidents as compared with those caused by automobiles, yet they may be considered in much the same way. Thoughtlessness, carelessness and ignorance are the chief contributing causes of accident and these may not always be charged against the injured person.

The first of several electrical accidents that have come to the attention of the Commission will be outlined and the reader will be allowed to judge whether the victim was responsible.

A workman, employed as a machine hand in a large shop, was standing on a steel plate that covered a floor opening between two machines. The plate was in contact with the frame of one of the machines, and this machine was accidentally charged with 440 volts. A metal hood had been provided to cover the motor, with a slot cut in the hood through which the wires were run between the terminals of the motor and a conduit fitting. The conduit had been terminated within a few inches of the frame of the motor, but was not metallically connected with or bonded to the motor. Vibration of the hood had chafed the insulation away from one of the conductors entering the motor and the hood was in metallic contact with this wire at the time of the accident.

When it occurred, the machine operator was standing on the charged metal plate and was pulling on a set of chain blocks supported from a bracket on the frame of an adjacent machine. This other machine was grounded and the operator was in good contact with this ground through the chain. Consequently, while he was standing on the charged steel plate, the circuit was completed through his hands and feet from one machine to the other.

The bank of 440-volt, three-phase transformers supplying the shop was not normally grounded. However, an accidental ground was placed on the system each time the motor starting switch for a small suspended grinder was operated. Within the conduit terminal fitting on the frame of this small motor, one of the wires or terminals was in contact with the grounded frame of the motor, so that each time the starting switch was closed it grounded the entire 440-volt system.

While the operator was pulling on the grounded chain and standing on the charged plate, another employee closed the starting switch for the grinder and a circuit was completed through the body of the operator, between the two machines, nearly a hundred feet away. Artificial respiration was tried, but he had been instantly killed.

The California Electrical Safety Orders require non-current-carrying metal parts of electrical equipment to be effectively grounded. Conduit terminal fittings must be provided at the frames of all motors and the wiring completely inclosed. Had such a fitting been provided at the frame of the motor where the insulation was worn off the wire, the accident could not have occurred. On the other hand, the fitting that was provided on the frame of the grounded motor operating the grinder did not give sufficient room within the casting to insulate properly and inclose the bolted connections when the cover was in place. When an order or rule is issued as a safety measure one can almost be certain that it was prompted only by past experience with the particular hazard.

Caution should not be confined alone to the operation of electrical equipment, but should be exercised in the design and manufacture of all materials and equipment that may be used in an electrical installation in use in an industrial plant.

In particular, care should be taken to see that electrical equipment and material are not installed in places or applied in types of service for which they are not intended by the manufacturer.

Construction details of

Short-Type Coils and Winding Molds

By A. C. ROE
and
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Consulting Editor, Industrial Engineer

THE SHORT-TYPE COIL derives its name from the fact that by its use, the over-all length of the armature is greatly reduced. This is accomplished by arranging the coil ends so that there is minimum projection beyond the core. This coil construction is a combination of the diamond and involute coils. Little information has heretofore been published on the construction and use of this type of coil. This article will, therefore, be of interest to repair shops and industrial plant men who have to rewind machines in which this type of coil is used.

THE short-type coil described in this article is a combination of a diamond and an involute type of coil-winding arrangement. A plan view, Fig. 1, of a short-type coil construction shows how the ends start away from the slot sections in a manner similar to the diamond coil and at a short distance are then squared off. The plane of the coil ends rolls 90 deg. at the change from diamond to involute. It is the squaring off of the diamond ends that gives the coil the name "short type."

The rear and front ends of a short-type coil are shown in Fig. 2. The center part that is shown three wires deep is the involute section of the end winding. The part to the right that is shown four wires deep is the top half, diamond-end part of the coil. This view also shows the roll or change in the plane of the diamond and involute sections. Fig. 2 also shows another characteristic of the short-type coil end—namely, in the change from the top half to the bottom half the wires roll over 180 deg. For example, consider the top wires of the bottom half of the coil, to the left in Fig. 2, which are the lead wires. Then follow these wires across the involute and note that they are now on the inside. On the right these wires are shown on the bottom of the diamond end and in the same position in the top side of the coil as it lies in the slot.

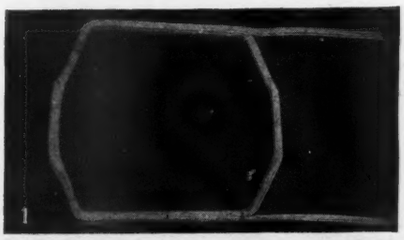
This practice brings out two rules that hold for all short-type coils: (1) With leads brought out on top of a coil as in Figs. 1 and 2, the starting lead in winding the coil is on the section of the coil that is to be in the bottom of the slot. (2) With leads brought out on the bottom of the coil, the winding of the coil must be started on the section that is to be in the top of the slot.

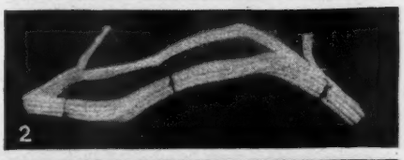
There are four distinct methods of winding short-type coils, and as each method calls for a change in the layout, an explanation of each method will be given.

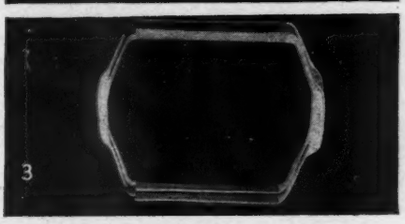
Method No. 1—The coils are wound single as in Fig. 3—that is, the total number of single coils used in any given armature must be wound and then 1, 2, 3, 4, 5, etc., single coils assembled after winding, in order to make a complete winding unit. For example, assume an armature having 49 slots and 97 bars, for which we would have to wind 98 single coils and assemble two single coils after being wound to make 49 winding units. The terms "two-coil tie," "three-coil tie," etc., indicate the number of coils to be assembled in order to make a complete winding unit. Fig. 3 shows a short-type, single coil with two coils assembled so as to make one unit or a two-coil tie. Such a coil is said to be "wound single."

Figs. 1, 2, and 3—Short-type coils wound in one operation.

The ends of the coil in Fig. 1 look like a diamond coil squared off. The end of the short-type coil in Fig. 2 shows the roll or twist of the diamond and involute sections. A short-type single coil is shown in Fig. 3 with two coils assembled to make one unit or two-coil tie.







Method No. 2—All single coils are wound on the mold together or a complete winding unit is wound at one operation. Figs. 1 and 2 show a one-operation coil, hence the term short-type (combination) or one-operation coil.

Method No. 3—In this method the location of the slot sections are one above, and one below, the throw line. Either the single or combination coil can be wound in this manner. The meaning of "above" and "below" the throw line is explained as follows: When making molds for the short-type coil, two sections of hard wood are used, but the two parts are not fastened together. One part is fastened to the winding machine, whereas the other part must be removable in order to permit the coil to be removed after it is wound. It is standard practice to lay the mold out with the throw line as the line of separation. The term throw line will be explained later.

In Fig. 4 the end view of a short-type coil mold is shown. The shaded section of the sketch represents one section of the mold and the light part the other section. The line XY is the throw line which separates the slot sections of the coil. The bottom slot section of the coil is shown below the throw line and the top half above the throw line.

Method No. 4—In this method both slot sections of the coil are above the throw line, as shown in Fig. 5. The short-type coil does not need a coil support. The involute section of the coil ends makes the construction rigid and when banded it is as good mechanically as any diamond coil with coil supports. The involute part of the coil also keeps the top and bottom

layers of the diamond parts of the coil end further apart, so that insulation between the coil ends while winding the armature is unnecessary with short-type coils.

When laying out a short-type coil for a given armature the following information must be known: The diameter and number of slots in the armature; the size of wire, turns per coil, and the arrangement of the wires in the coil (that is, the number of wires deep and wide); insulation on coil ends and in the slot section; the distance the coil can extend out from the core on both ends; and how much the winding can drop below the outside diameter and still clear oil throwers, thrust rings, etc.

There are certain basic dimensions used in laying out a short-type coil, and these may be obtained mathematically or by direct measurement from the armature. The coil can then be laid out on a paper to full scale or half size.

The first step is to draw a line representing the outside diameter of the armature, as an arc or line *A* in Fig. 6. Next draw in the lines *2* and *3*, to represent the center lines of the slots in which the coil lines are drawn. Angle *O* equals $(360 \div N) \times$ coil throw or pitch in slots, where *N* equals the total number of slots. The chord of the angle *O* on the outside diameter *A* in Fig. 6 equals the diameter of the armature times the sin $O \div 2$.

A practical method of locating the lines *2* and *3* in Fig. 6 is to plug two slots (the coil pitch part) with wood blocks cut off flush with the top of the armature but projecting beyond the end of the core. Then with a pair of dividers lay off the distance between the center lines. Transfer this dimension to the drawing and draw in the lines *2* and *3*. Next, mark off the bottom of the slots on these two center lines and from line *A* in Fig. 6 lay off on the center lines a distance equal to the thickness of wedge used. Midway between these two points draw the line *B*. This line represents the line on which the bottom of the top half of the coil and the top of the bottom half of the coil lie when leaving the slots.

Next, the line *TL*, or throw line, is drawn from the points on the center lines of the slots where the line *B* crosses them. Thus, in this case the throw line is the distance between the center line of the bottom of the top half of the coil and the center line of the top of the bottom half of the coil, as points *a* and *b* in Fig. 6.

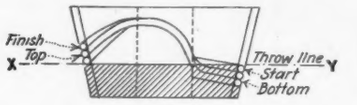


FIG. 4

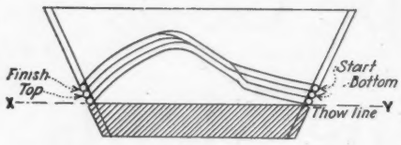


FIG. 5

Figs. 4 and 5—End views of mold for winding short-type coils.

Fig. 4 shows the top side of the coil above the throw line and the bottom side of the coil below this line. In Fig. 5 both top and bottom sides of the coil are above the throw line.

The coil sections shown in Fig. 6 need not be drawn in, but they are shown in this case only to help in the understanding of the various lines and their relations.

The distance *d* from line *3* to line *5* is the thickness of one insulated wire or single coil. The angle *M* is the distance between the center lines of the adjacent slots and equals $360 \div N$. The chord *C* equals the diameter of the armature times sin $M \div 2$. This also can be measured directly on the armature with the dividers. The depth of the insulated wires in the slot is indicated by *WS*, as the wire space in Fig. 6.

We are now ready to lay out the end winding, which is done in the same manner as for a diamond-shaped coil, and is illustrated in Fig. 7. First draw the line *XY*, which represents the end of the armature core iron, and then the line *CD*, which represents the distance the bottom cell projects beyond the iron. Next draw in the line *AB*, which is the distance the top cell extends beyond the core. The distance *F* is the difference between the top and bottom cell extensions.

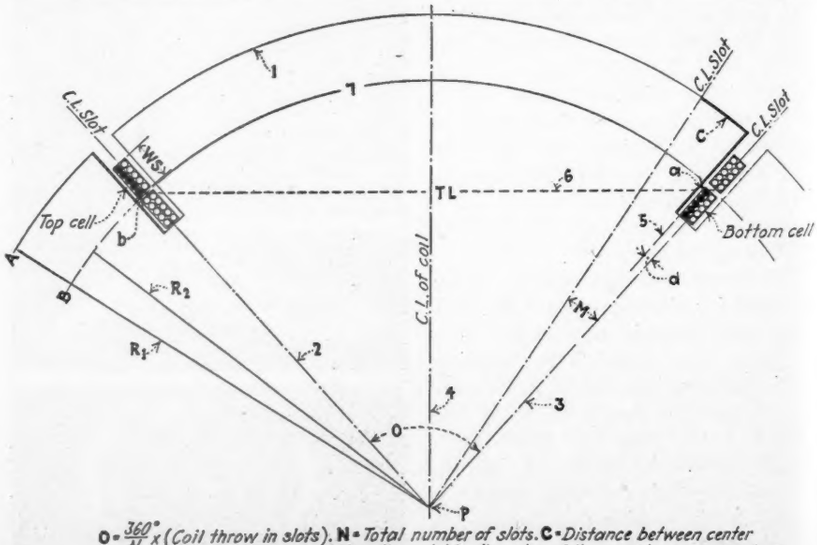
Next, the distance *P* is determined, and it is found to be equal to $R_2 \times 6.2832 \times T \div N$, where *T* equals the pitch of the coil expressed in slots. That is, for a coil pitch of 1 and 1*P*, *T* equals *7*. R_2 is taken from Fig. 6.

With *P* known, lay off lines *4* and *5* as shown in Fig. 7. Then find the distance *S* equal to *T*, which is also the developed distance between the center lines of slots on the line *B* of Fig. 6.

Next, find the insulated thickness of the coil at *L* as in Fig. *7A*, plus any air space required between the ends, and with *L* as a radius describe arcs *9* and *10* in Fig. *7*. From point *A*, Fig. *7*, draw a line that just touches or is tangent to the small arc *9*. This is line *AE* in Fig. *7*, and from the point *D* draw the line *DE* also tangent to arc *10*. This line may meet line *6* at the point *E*, or below it. The point *E* in Fig. *7* indicates the position of the center line of the pin for a diamond coil.

The next step is to find the distance *EX* (Fig. *7A*), which represents the extension of the center line of the involute *JK* beyond the core or line *XY*. This can be determined from the amount of end room available, but in locating the line *JK* allowance must be made for the distance *(WS* plus the insulation$)+2$, which is one-half the wire space plus the insulation used on the coil ends. That is, the total coil extension is *EX* $+$*(WS*$+$the insulation$)+2$. Measure this distance on line *6* from line *XY*.

Fig. 6—This diagram shows how to lay out a short-type coil from the measurements taken from an armature.



$O = \frac{360°}{N} \times$ (Coil throw in slots). **N** = Total number of slots. **C** = Distance between center lines of adjacent slots measured on the outside diameter of the armature or on arc *A*
M = Angle between adjacent slots = $\frac{360°}{N}$

and draw line *JK* until it meets lines *AE* and *DE*. Then from points *J* and *K* drop the perpendicular lines *14* and *15* and divide the distance *P* into three parts as *H*, *M*, and *N*.

The distance *M* in Fig. 7 is the length of the involute and it is seldom found to be greater than 40 per cent of the distance *P*, but, in general, the longer the line *JK* or distance *M*, the deeper the end winding will be and the shorter the distance *EX* (Fig. 7*A*). Thus the two limits are coil extension and depth.

In Fig. 8, diagrams *A*, *B*, and *C* show the various steps in building up the layout of Fig. 7. We can obtain from Fig. 7 a tentative location of the involute to use in Fig. 9 in order to finish the layout. Space off the distance in Fig. 7 between the center lines of the slots. We find, then, that point *K* falls on the center line of slot *5* and that point *J* is approximately ⅛ in. to the left of the center line of slot *9*.

Fig. 9 is the same as Fig. 6 except that the arc *3* has a radius equal to R_3, or the diameter of the smallest circle that the bottom of the involute can ride on. Thus, R_3 is the maximum depth of the winding. Points on the outside radius *A* have been laid off equal to the distance between the center lines of slots *1* to *13*. In Fig. 9 from points on arc A drop lines KK_1 and JJ_1, locating the distances *N*, *M*, and *H* on the correct throw line, *TL*. Next, draw the arc or line *4*, which is equal to R_2 plus the wire space. This line represents the top of the coil.

From point *C*, which is the bottom of the coil at the center line of slot *1*, draw a straight line to the point on arc *3* where line KK_1 meets it, and from point *B* draw a line, *6*, parallel to and a distance *WS* above line *5* until it meets line KK_1. Call this point *S*. Point *S* falls below the throw line, for the case under consideration, but it can be above or below it. This point *S* is one of the most important factors of a short-type coil, as it affects the winding of the coil and also the winding of the armature. The farther point *S* falls below the throw line the harder it will be to wind the coils, as the wires will fall down on the bevel with the first turn on the throw line, as shown by the small circles in slot *1*. This first turn must be held up so that the second and succeeding turns can be wound.

On the other hand, if point *S* is brought up above the throw line, it means that the involute is flattened out, distance *N* is increased and *M* decreased. If this is done, there will be trouble in winding the armature, as the winder will have to beat coil point *S* down to prevent the top section of the coil projecting above the line *A*, the outside diameter of the armature. But the angle *O* and line *EX* in Fig. 7 limit the amount that point *S* can be varied, so that the only other thing to do is to ease up on the bevel used on the mold for the bottom slot section, or reduce the pitch of the coil by one slot.

It is plain, therefore, that care must be exercised in selecting point *S*. In order to reduce the distance K_1S (Fig. 9), the length of *N* must be increased, which in turn means that the line *EX* must be lengthened or the coil extension increased. If point *S* is satisfactory, then the distance *T* can be measured directly from the layout.

The next step is to check the angle of the involute section to determine whether the coils will wind without building up. This can be done in the layout, Fig. 9, but to make the method clear a separate sketch will be used.

In Fig. 10 line *A* is the same as in Fig. 9. Then on this line, starting at

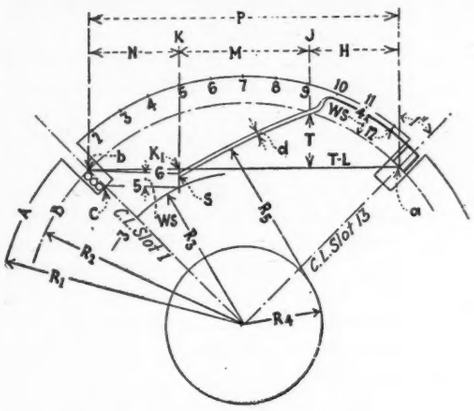


FIG. 9

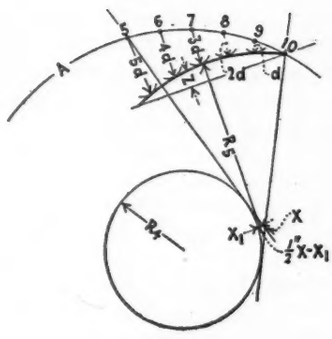


FIG. 10

Figs. 9 and 10—These diagrams show how the involute section of the coil end is constructed.

The diagram in Fig. 9 is the same as that in Fig. 6. The diagram in Fig. 10 supplements that in Fig. 9 and shows how the angle of the involute is determined so that the short-type coil will wind properly.

Figs. 7, 7A, and 8—The shape of the ends of the coil is determined as shown in these diagrams.

The steps in the construction are shown in Figs. 7A and 8. Numbers *1* to *15* indicate the order in which the dimensions are used.

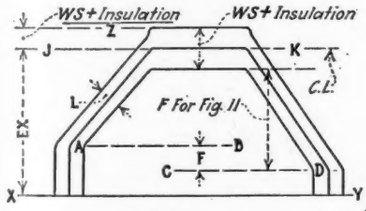


FIG. 7A

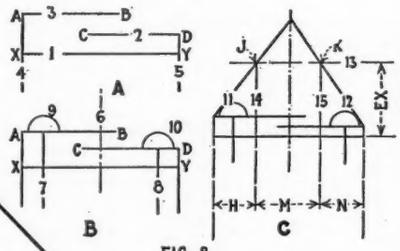
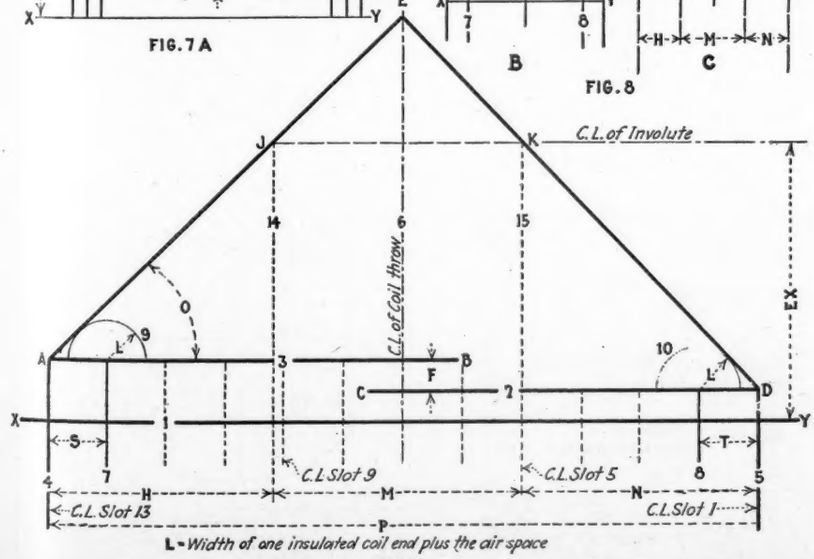


FIG. 8



L = Width of one insulated coil end plus the air space

FIG. 7

any position, lay off six points as *5, 6, 7, 8, 9,* and *10,* representing the center lines of slots. From point *9,* Fig. 10, describe the small arc as shown, the radius of this arc being equal to *D* of Fig. 9, which is the insulated thickness of the complete coil at the involute section. This dimension *D* also includes any air space wanted. Then from point *8* describe the next small arc with a radius of *2D,* and from each of the other points describe small arcs with a radius as indicated in Fig. 10, which is equal to the number of coil ends that must pass the point in question.

The next step is to find a radius *R5* that will touch all small arcs. One method is to draw the small circle with a radius *R4* (Figs. 9 and 10), which radius is equal to $(N \times L) \div 6.3$. Then from points *5* and *10* in Fig. 10 draw two lines as shown tangent to the *R4* circle. Midway between the point *x,* where these two lines cross, and the circumference of the *R4* circle will be found the center point of a radius, *R5,* that will touch all the small *d* arcs.

It will be noticed that the slots *5, 6, 7, 8, 9,* and *10* used in Fig. 10 were taken from Fig. 9 to be the points that fall on line *KJ.* When the distance *Z* (Fig. 10) does not exceed ¼ in., or ⅜ in. for light coils, the involute part may be made a straight line. This line is drawn from point *S* (Fig. 9) to the point on the line JJ_1 *T* inches above the throw line.

The next step is to record the dimensions found by means of the coil layout in a form that can be kept and used in the construction of winding molds. The form shown in Fig. 11 can be used for all short-type coils wound single or in one operation and with cells, one above and one below the throw line.

The bevels *Q* and *S* are obtained from Fig. 9 by erecting a perpendicular line from points *a* and *b* and measuring from the throw line to the point on this line where the center line of the slot is 1 in. from the line. This is shown in Fig. 9 at the center line of slot *13.* The letters in the sketch (Fig. 11) show the location of each corresponding letter as found in the layouts and insures a standard method of recording dimensions. After the terms *leads on, start on,* and *wound,* two classifications are given. The one not used is to be crossed out. The remaining terms give full data for making future coils. The addition and filling out of the terms, *wound single,* or *one operation,* is important, for the dimensions *B, H* and *N* must be changed to suit the type of coil.

In Fig. 9 the throw line is shown as being the distance between the center line of the bottom of the top half of the coil and the center line of the top of the bottom half of the coil; this is the standard designation for the *B* dimensions. But this is not always correct, for in coils wound single and consisting of more than one single coil per winding unit the discrepancy is greater the larger the size of wire and the number of single coils used.

Figs. 12, 13, 14, and 15 show the effect of making the *B* dimensions on the mold less than the throw line. In Fig. 12 a single coil is shown, with the throw line to the center of the coil. Then as the coil is actually wound on, the line *AC,* which is $d \div 2$ less than the throw line dimension (where *d* is the insulated diameter of the wire used), it follows that the finished coil is $d \div 2$ wider than the layout dimensions. This extra coil width depends on the size of the wire, and in cases where the slot is deep, it will facilitate pulling the top half of the coil over the tooth and into the slot.

Two single coils are shown in Fig. 13. The center line of the slots falls between the two single coils. The black circles indicate the one single coil that would be wound on the mold, and as the bottom side would be wound on the line *AC,* it is evident that if the *B* dimension is the same as the throw line, the coil will be wider than the layout coil by an amount equal to *d.*

Fig. 14 shows a three-single coil, which falls into the same class as those in Fig. 12.

A four-single coil, shown in Fig. 15, is the same as those in Fig. 13. This leads up to the rule that for a unit having an odd or even number of single coils, the *B* check will be *d* greater than the layout throw line.

Fig. 11—Data form for recording the information from coil layouts for the construction of winding molds.

Mold Data for Short Type Armature Coil

_____ Hp. _____ Volts _____ RPM. _____ Poles

Type _____

Diam. of Arm _____ Length of Coil _____ No. of Slots _____

Coils per Slot. _____ Turns per Coil _____ Size of Wire _____

Coil Pitch _____ Wire Space _____

A _____ K _____

B _____ R_2 _____

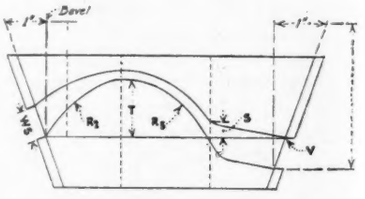
H _____ T _____

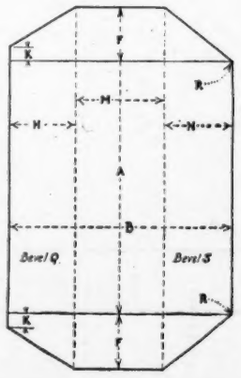
M _____ S _____

N _____ Rs _____

F _____ Bevel Q 1 in. x ____

R _____ Bevel S 1 in. x ____





Leads On Bottom / Top

Start On Bottom / Top

Wound Single / One Operation

Winding Mold No. _____

These rules apply only to coils wound single. It also means that with large wire, and for close design, the variations as outlined must be taken into consideration. In most cases, however, the *B* dimension on the mold sketch can be made equal to the throw line as found in Fig. 9.

In Fig. 11, the distance *K* is the amount the top cell projects beyond the bottom cell on one end and in most cases is ¼ in., but for coils wound with wire of large size, as No. 8 and above, it may be as much as ⅜ in. The distance *A* equals the length of the armature core plus any coil extension. The amount the bottom coil extends past the core should not be less than ¼ in. for voltages up to 600 and should be ½ in. when end room permits. While ¼ in. to ¾ in. is the range, it can vary depending upon the end room and size of wire. A heavy coil will require more slot extension than a light coil, which is due to the fact that the bevels of short-type coils are seldom correct and placing the top half of the coil in the slots tends to twist the bottom section. Also, the longer cell extensions allow more spring to the coil in pulling it over and into the top slot.

The dimension *R* is the radius used on the mold at the ends of the slot sections, and varies from $\frac{1}{16}$ in. to ¼ in., the $\frac{1}{16}$-in. value being used for wire up to No. 15, and ⅛ in. for No. 14, and the larger sizes. The radius *R* used decreases the total length of the straight part and with any given set of values for Fig. 11 the total length of the slot sections depends on the bevels *S* and *Q*, the wire space, and the dimension *F*, which will be explained later. The dimension *F*, Fig. 11, is the distance *EX* of Fig. 7 less one-half the wire space or *EX*—*(WS*÷*2)*, as shown in Fig. 7*A*.

The next step is to show how the *B* dimensions for the mold sketch in Fig. 11 must be corrected for coils that are to be wound in one operation and that have been laid out as indicated in Figs. 6 and 9.

Fig. 16 shows a single coil. The *B* dimension of the mold would be equal to *AB* on the throw line *TL* of Fig. 16, but the correct *B* dimension is *CD;* therefore, for single coils the *B* dimension can be made to the center lines of the slots.

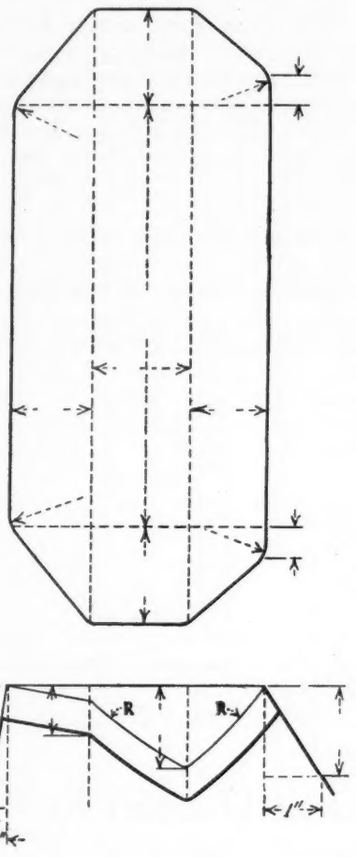


Fig. 20—Form of winding mold for coils with both sides above the throw line.

Fig. 17 shows two single coils. The *B* dimension for a coil wound single would be *AB;* then for the single-operation mold, the *B* dimension should equal *AD* on the line *TL* of Fig. 17. This would give the finished one-operation coil the same correct *B* check as the wound-single assembled coil, unless the wound-single coil had been wound to the *AD* line. Then the one-operation coil would have to be wound to the *CD* di-dimension.

Fig. 18 shows three single coils wound with *B* equal to *AB*. For the one-operation mold, the *B* dimension should equal *EF*, or *AB—2d*, where *d* is the insulated diameter of one wire. If the wound-single *B* dimension were made to the correct *B*, as *CD* of Fig. 16, the one-operation *B* for Fig. 18 would equal *CD*.

Fig. 19 shows four single coils. If the wound-single *B* dimension were *AB*, the one-operation *B* dimension should equal *AD;* but if the wound-single *B* dimension had been equal to *AD*, as in Fig. 17, then the *B* dimension for the one-operation coil for Fig. 19 would equal *CD*.

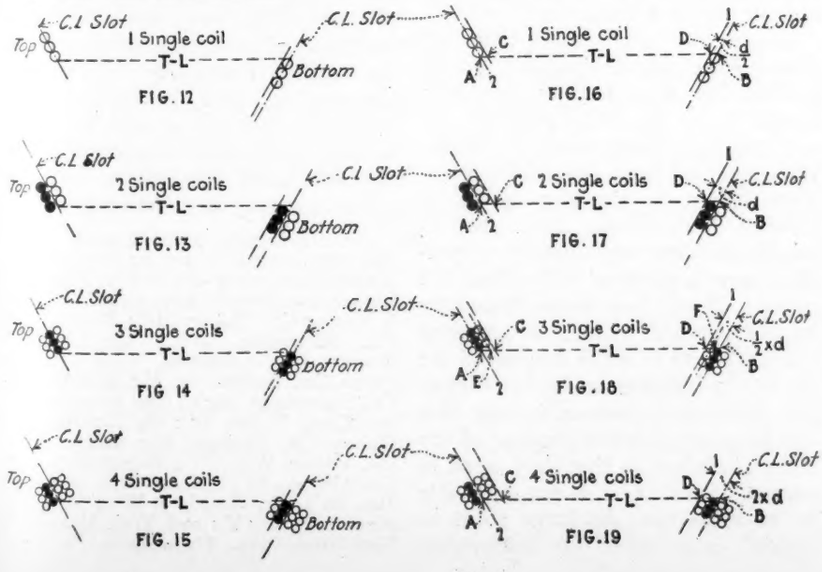
Thus the method of winding the coil changes the *B* dimension on the mold; also, if the coil is laid out as in Figs. 6 and 9 and then changed to a one-operation, the dimensions *H* and *N* should also be changed.

When a coil is being designed, the advantage of the distance between points *C* and *B* on the throw line can be used or discarded according to the depth of the slot and size of wire, and the pull required to get the top half of the coil over and into the top slot.

When a mold sketch is being made from a sample coil, always use the inside *B* dimensions as *CD* for either the wound-single or the one-operation coil. If the sample coil has been wound satisfactorily, then the new coils should be exact duplicates.

Figs. 6 and 9 use the coil layout of one side above the throw line and one below, but in some cases when the point *V* in Fig. 11 of the mold breaks down during winding or when it is hard to get the mold apart, the coil can be laid out as explained. Then a line is drawn from point *A*, Fig. 9, to point *C*, or to the center line of

Figs. 12 to 19—These diagrams show the effect of making the B dimension of the winding mold equal to, less, or greater than the throw line.



the bottom of the bottom half of the coil, thus placing both coil sides above the throw line. The dimensions *T* and *SK* must be scaled off, for they will be changed.

Putting both coil sides above the throw line also results in the straight part of the bottom slot section being equal to *A* less *R*, as in Fig. 11. The top of the bottom half of the coil would be longer than *A*, whereas with one cell below and one above the throw line, the bottom part of the bottom half of the coil would be shorter than *A* less *R*, the amount depending on the bevel *S*, the dimension *F*, and the wire space.

This falling away of the straight part, due to the compound angles, is important and should be checked, as the length of the straight part limits the length of the insulating cell that can be put on the slot section of the coil without wrinkling. On close designs, the placing of both cells above the throw line will insure maximum cell lengths in every case.

The above facts should be kept in mind when changing an existing coil that has been designed and wound on a mold with cells one above and one below the throw line to one having both above the throw line, as the dimensions *T* and *S*, Fig. 11, must be changed as well as the *B* and *H* dimensions. But angle *CDE* of Fig. 7 is more important. This should be checked, as changing the bottom cell to a position above the line will lengthen the top of the bottom cell, and if the coil angle was close before the change, the bottom coil ends will bind and prevent the coils from winding. A mold form arranged for coils with both cells above the throw line is shown in Fig. 20.

All the above points can be tried out on a sketch drawn to scale or by binding a heavy piece of wire and trying it in the armature. After a few trials, however, the layout will be found to be less complicated than it seems for the short-type coil.

Applications of Unit Heaters in Industrial Plants

(*Continued from page 353*)

stop and the heat from the radiator would then affect the thermostat and shut off the steam. In this way the unit automatically shuts off the steam at night when the fan is shut down, but in case the room should become cold would turn the steam on again and so prevent the unit from freezing.

Because of the thermostatic control of the steam line it is unnecessary to make any adjustments of the valves and no one is permitted to touch them during the heating season. Even though the steam is shut off when the temperature of the recirculated air gets above a certain point, the fan continues to circulate the air; thus any drop in temperature affects at once the thermostat and the steam valve. On this regulating unit it is not necessary to use a compressed air line because the thermostat is placed close to the valve it controls. If the thermostat were placed some distance away from the unit heater and controlled it according to the temperature at that point, it would be necessary to run a compressed air line to the unit to operate the valve.

Still another type of thermostatic control shuts off or turns on the motor driving the fan. This thermostat is placed at some distance away so that it would not be affected by the radiator in case the fan were shut off. A common type of such thermostatic control is known as the Mercoid (American Radiator Company) which makes and breaks a circuit through a mercury contact which is controlled by the temperature. Although these thermostats may be placed at some distance from the heater, it is merely necessary to run a control line between the thermostat and the motor circuit.

There are still other types of thermostatic control available, but in general they control either the power to the fan or the steam supply.

When unit heaters are to be installed in buildings, one of the principal points to consider is to so arrange the various units that as nearly uniform temperature as possible may be obtained throughout the room. This is best accomplished by having a number of units so arranged that they tend to set in motion all the air in the building or room. Unless the building is unusually long this can be accomplished by having all the units discharge so that they work in unison. That is, it is not advisable to have the fans discharge so as to "buck" each other by discharging toward each other. In such a case the cold air would be back of the fans and the warm air between the two. For example, in a long narrow room or building (if not too long) it would be better to place two heaters, about 20 ft. apart, near the center of the building, discharging in opposite directions. For an ordinary building it is usually well to have the discharge end of the heaters so placed that each will discharge toward the next and thus cause the air to circle the building. This is shown in the sketch on page 353. Also it is well to direct the discharge of at least one of the heaters toward the worst exposure.

If the building is more than 15 ft. in height and overhead heaters are used it is sometimes advisable to arrange to take from the floor line the air which is blown over the heaters. This procedure heats the coldest air by removing it from the floor and causes the warm air to be sent to replace the cold air removed. If, however, the building is not very high it is generally not necessary to do this. Frequently the same results are obtained by using a deflector which tends to turn the warm air down toward the floor. However, the deflector should always be placed so as not to direct the air toward workers.

In general, more uniform and satisfactory results are obtained by installing a number of smaller units rather than one or two large ones. Greater economy of operation is also possible, because in mild weather fewer heaters need be used to maintain a uniform temperature. With only one or two large units this cannot be done. Furthermore, if only one or two large units are used, the air returning to them at times creates an objectionable draft around the unit. Practically all manufacturers of unit heaters make a variety of sizes so that with any type selected it is possible to choose a suitable size, with the largest sizes reserved for very large buildings.

NOTE: Acknowledgment is made to the following companies for information and illustrations used in this article: American Blower Co., Detroit, Mich.; Autovent Fan & Blower Co., Chicago, Ill.; Bayley Mfg. Co., Milwaukee, Wis.; The Buckeye Blower Co., Columbus, Ohio; Buffalo Forge Co., Buffalo, N. Y.; Clarage Fan Co., Kalamazoo, Mich.; The Herman Nelson Corp., Moline, Ill.; Ilg Electric Ventilating Co., Chicago, Ill.; Modine Mfg. Co., Racine, Wis.; The Powers Regulator Co., Chicago, Ill.; Skinner Bros. Mfg. Co., Inc., St. Louis, Mo.; L. J. Wing Mfg. Co., New York, N. Y.; and York Heating & Ventilating Corp., Philadelphia, Pa.

Oversights That Cost Money

Here is an example that may easily be overlooked by you, but not by the railroad

THERE are times when all of us have wished we could be set back ten or twenty years and have the opportunity to do certain things over again in the light of experiences that have brought a fuller knowledge or understanding of our work. When we get into this mood, it is a good time to sit down and put on paper the corrective thinking that we can now apply to a particular problem. The reason for doing this is not so much to get a printed record of it as to make it available to others who must certainly travel paths similar to those we have traveled and be forced, as we were forced by circumstances or lack of knowledge and experience, to make mistakes that could have been avoided.

EVERY superintendent who has spent fifteen years or more in plant work knows that it is a most difficult job to find a ready-made assistant, and realizes what a long and patient job it is to train one. The experiences of you men who have successfully done this job would be most valuable information for the young operator who aspires to a position at the head of a large shop or organization. Things to do and not to do, including the handicaps to overcome in misdirected ambition, jealousy, and temper, are also possible subjects. But most helpful of all would be a discussion of the things that are expected of a young man who has the ability and make-up to carry successfully the title of plant superintendent. This information in the form of actual experiences on a particular job would be welcome as articles for publication.

I RECALL a recent conversation with a superintendent who complained bitterly about the carelessness of an assistant in regard to a purchase on which there had been unnecessarily heavy freight charges. This shipment was a single-width, single-inlet ventilating fan that was too large to go through the door of a standard box car. These doors are 7 ft. 6 in. high by 6 ft. wide.

THE fan weighed only 3,900 lb. but because of its size it came under Rule 29, Section 3 of the Consolidated Freight Classification No. IV, and the freight was considerably more than it would have been had the fan been ordered shipped knocked down instead of assembled.

The difference in the amount of the freight was not the subject of complaint; it was the fact that the young man had not thought to order the fan knocked down, for he knew that when assembled it could not be taken to and installed in the space provided for it. It is probable that he will not make this mistake again. The reason for it was that he was too busy thinking about the job for which the fan was to be used, to stop and think over the best way to ship it, that being considered a manufacturing problem and not an operating problem.

THIS one incident may recall many others of a like nature to you men who have been most of the way through the mill. In this connection just remember that it's our job to make successful foremen and department heads just as well and successfully as we make pig iron, plowshares, automobiles or what not. Think about this and out of your experience send me something that will help to keep the young operator from making the mistakes we did and, incidentally, save the expense that many of them cost us in money, time, and humiliation.

Practical Pete

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

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G. A. VAN BRUNT, *Editor*

New York, August, 1927

Standards for Industrial Gears Are Now in Sight

THE American Gear Manufacturers Association has undertaken a constructive program of standardization that will be of benefit to every industrial operating man.

At the present time difficulty is often experienced in ordering or making a duplicate gear or pinion, especially when it is not possible to obtain this from the original manufacturer who is able to refer back to his drawings for the proper dimensions. Much of this trouble is due to the various so-called "standards" in vogue during the past few years. Many of these standards are in reality shop practices and altogether too often each shop established its own practices. Although many of the differences in standards are on minor points, thev have considerable effect upon matching the gear or pinion with its mate.

Trouble of this nature will be eliminated, particularly in the case of gears made in the future, by the work that is now being done by this association, whose members represent many of the largest manufacturers of industrial gears.

In addition, studies are being made of the permissible gear tooth loads, with particular attention to the high speeds of modern industry and the newer non-metallic gear materials. Work of this nature is of much importance to gear users. The old formulas for gear design were based on data collected when gears were not subjected to the speeds and loads that are common in present-day practice.

The activities of the American Gear Manufacturers Association in behalf of gear users are highly commendable.

Tell Us How You Have Solved Your Power Drive Problems

IN NEARLY every industrial plant of any size there are one or more power drives that cause an excessive amount of trouble. Operating conditions may be unusually severe, the drive may have been poorly laid out, the equipment improperly installed, or a variety of other causes may have operated to produce a drive that has always been unsatisfactory and troublesome.

Oftentimes, by the exercise of some ingenuity and possibly with the assistance of some manufacturer of power drive equipment, the plant man succeeds in overcoming the trouble and works out a drive that operates satisfactorily.

In many other instances the correct answer to the problem has not yet been found, and an inefficient, troublesome drive is being nursed along and kept going largely by "main strength and awkwardness," as the saying is.

There is no particular rule or formula that can be applied to the solution of such power drive problems. Each case must be studied individually, and all of the conditions and requirements analysed and evaluated. If it is possible to make any of the operating conditions less severe, this should be done. In any event, it is safe to assume that there is available a sufficient variety of power drive equipment, and enough experience and information regarding its application, to solve any operating problem in a satisfactory and economical manner. It is, however, necessary to use this information intelligently, and in the light of a definite knowledge of all pertinent factors bearing on the drive in question, in order to make sure that the combination of equipment employed is the best and most efficient for the application.

The Editors of INDUSTRIAL ENGINEER are making a detailed study of difficult and unusual drives, the results of which will be reported in an early issue. Operating men who have satisfactorily solved some difficult power drive problems, or who are still trying to do so, are invited to send full details to the Editors.

When Fewer Men Do More Work

MOST of us remember such school-day problems as, "If ten men can do a job in thirty days, how long will it take thirty men to do it?" According to the answer given in the back of the book, the thirty men would finish up in ten days. However, many industrial plant men have learned that when they tried to work this problem out with men the answer is more likely to be twelve or fifteen days, instead of ten.

This apparent discrepancy does not prove that the laws of arithmetic are variable. It does show, nevertheless, that the problems incidental to handling men and work are variable. The reason for this variation is generally to be found in the ability of the man who is responsible for selecting the workmen and overseeing their work, rather than in the ability of the men themselves.

An interesting example of this was recently shown in one industrial plant. The machinery, lineshafts, motors, and other equipment had to be installed in a new building. To speed up the job about fifty new men were hired, and five of the ten

men composing the regular crew were put in with the new men.

The man in charge had always looked closely after details and handled his small force well. With the big addition to his crew he still tried to do all the supervising himself, as he had no one capable of acting as assistant foreman. As a result he soon found himself swamped. Everyone waited for instructions, and in many cases did not take the trouble to hunt him up, but waited, sometimes for several hours, until he came around. Thus many of the men were practically idle a considerable part of the time.

The force was eventually cut about in half. With the smaller number of gangs supervision was comparatively easy; in consequence more work was done.

Although construction and maintenance work in many plants is suffering from lack of enough men to handle it properly, little is gained by hiring more men than can be given adequate supervision. When unusually large jobs are to be handled much more can usually be accomplished by carefully planning and directing the activities of the regular force, with perhaps a few extra helpers, than by adding more men than can be given such careful supervision.

Motor Troubles with Short-Center Belt Drives

CONSIDERABLE liberty is too often taken with good operating practice for center distances when leather belts are used. When motors of 5-hp. rating and larger are installed with pulley centers of less than 10 ft., and no provision is made for the use of special belt tighteners, motor troubles can be expected sooner or later. This is particularly true if the motor operates continuously close to its full-load rating.

In the first place, when centers are too short and the motor pulley is of the standard diameter, say 4 or 5 in., the contact surface is too small to allow the driven machine to be accelerated as fast as a squirrel-cage motor comes up to speed. As a result the belt slips off. This is usually taken by the operator as a signal to tighten the belt, and then real trouble begins.

Excessive belt tension wears down bearings, causes the motor to run hot and will probably blow fuses. If magnetic switches are used the overload relays will trip and give some thoughtless operator, who knows little about these switches, an excuse to adjust the relays beyond the safe setting for motor protection.

The result of all this procedure shows up finally in burned-out bearings or windings, or both—and in most cases it is both. In either instance, the cost of repairs to bearings or windings will be much more than the extra cost of a belt of the proper length and width to handle the motor load.

No single piece of equipment in a plant will stand more abuse or give longer and better service than a good leather belt, but abuse of belts in narrow widths and single-ply weights on short centers can never be excused.

If there are any short-center belt drives in your plant at this time we suggest that you inspect the record of motor repairs for such drives. If any one motor that is not overloaded has a rewind job charged to it, change the belt to the width and length that standard handbooks give as good practice for belt drives.

Overcome Conditions That Limit Production

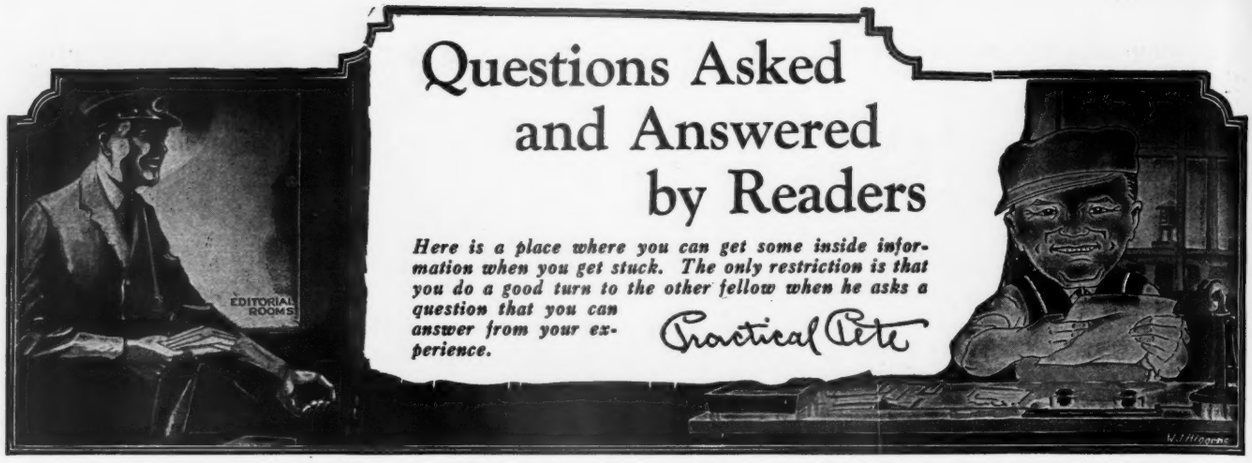
FOR every industrial operation there is a practical limit which determines the quantity, cost, time, or other economic factors in that operation. Material handling is one of the best examples of the importance of this practical limit, and incidentally provides numerous instances where this limit has been studied and increased to considerable economic advantage.

For example, wire-drawing operations were in the old days generally limited by the weight a man could handle. When hoists, alone or in combination with conveyors, were adopted the limitation imposed by the strength of the operator was reduced so that larger rolls meant less frequent and shorter stops, and less waste.

Problems incidental to handling bulky but light products, where the size or bulk established the handling limit, were overcome by the use of special carriers which were large enough to take a greater number of the bulky units at a time. The use of special grappling devices for lifting or holding, yokes for non-magnetic materials and magnets for handling iron or steel products, increases the unit load and also decreases the time required for picking up and putting down a given quantity of material. A truck that can lift, carry, and pile, or handle 2 tons at a time instead of only 1, is also reducing the cost of production by decreasing the former limitations.

Many other instances where a hoist, conveyor, truck, or other piece of material handling equipment, or specially designed attachment for such equipment, has gone beyond the limit of muscle power, or replaced other equipment of limited capacity, could be enumerated.

Every operating man has the opportunity to suggest and put into practice new ideas that will not only remove limitations to production but reduce production costs as well. The cost of handling is not only an important element of production costs, but is frequently one of the easiest to reduce.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

QUESTIONS
Who Can Answer These?

Protecting Small Transformers From Shorts and Overloads

We use several small 110-volt transformers for operating our bell and annunciator circuits. These transformers frequently burn out, apparently from short circuits or overloads. If fuses are used to protect these transformers, should they be placed in the primary or secondary circuits? Is there any better way of protecting the transformers? It may be that readers can tell me of a more dependable method of supplying the necessary current. R. S. T.
Worcester, Mass.

Charging Storage Batteries From Exciter

In our plant we have a combination signal and fire alarm system operated from three 6-volt, lead batteries connected in series. Instead of sending them out every month, I want to charge them from the 125-volt exciter on our generator, which is in continuous service. In order to lower the voltage for charging I want to use a number of spare cast-iron grids that are kept on hand for a 50-hp. motor. Will readers, therefore, suggest a method of determining the resistance per grid, so that I can determine how many to use? R. C. B.
Grenada, Miss.

Determination of Motor Rating for Capstan

We wish to haul our department trucks at a speed of 2 miles per hour up a concrete ramp that is 40 ft. long and has a pitch of 30 deg. These trucks, which have a loaded weight of 900 lb., have rubber-tired wheels. The hauling is to be done by a capstan located at the top of the ramp. I wish readers would tell me how to determine the proper size and speed of 550-volt, three-phase a.c. motor, size of capstan drum and reduction gear ratio that should be used for this job.
Altoona, Pa. G. M. E.

Cause of Low Voltage On Exciter

Our company recently installed a 250-kw., three-phase, 60-cycle, 440-volt, 328-amp., belt-driven generator. It is separately excited by a 23-kw., 125-volt, 183-amp. compound-wound generator, which is driven by a belt from the a.c. generator shaft. The exciter heats badly, and will not build up a voltage over 100. In order to maintain the 440-volt line voltage, it is necessary to operate with one rheostat wide open and one completely closed. Will readers please tell me what is causing my trouble? J. J.
St. Mullins, S. C.

Driving Lineshaft By Two Motors

Several machines are operated from one lineshaft in our mill. On some days the load on this shaft is 15 hp. while on others it is 50 hp. We have two 25-hp., constant-speed, shunt-wound motors on hand, and wish to connect them to the shaft through clutches. When the load falls below 25 hp., one motor can be shut down. Will readers tell me (1) whether these motors will operate properly if connected to the same shaft? (2) Is this plan feasible? (3) Is it possible to operate in this manner two constant-speed compound-wound motors, two series motors, or two adjustable-speed, shunt motors? E. K.
McKeesport, Pa.

Emergency Lighting from Current Transformer

We have a 440-volt motor in service at a considerable distance from the 110-volt lighting system. In the one phase of the motor circuit there is a 20:5-amp. current transformer for operating overload trips. Inasmuch as we do not want to extend the lighting system for only one lamp, and do not wish to install four lamps in series, will readers tell me whether I can cut a lamp in the secondary circuit of the current transformer? If so, what size and type of lamp should be used? A. K. R.
Superior, Wis.

Motor Current Increases When Neutral Is Connected

We have a three-phase, four-wire, 60-cycle, 4,000-volt, 21.7-amp., 185-hp., 900-r.p.m. unity power factor synchronous motor direct connected to a 440-volt a.c. generator. Running without load at unity power factor and with the neutral disconnected, the current in each phase is 2.4 amp., but when the neutral is connected 30.5 amp. flows in the neutral and 10.32, 10.5, 10.5 amp. flows in phases A, B, and C, respectively. Although this motor has given similar trouble on another line, there are other four-wire, 4,000-volt, Y-connected synchronous motors operating successfully on this circuit that has a power factor of 98 per cent lagging. The field coils in this motor are in first-class condition. Any suggestions from readers that will enable me to remedy this trouble will be appreciated.
Ft. Wayne, Ind. J. L. D.

ANSWERS
Received to Questions Asked

Advantages of Three-Phase, Four-Wire System

As there seems to be an increasing use of three-phase, four-wire systems, I shall appreciate it if some reader will answer the following questions. What are the principal advantages of a three-phase, four-wire system over a three-phase, three-wire system? Are there any special conditions under which these four-wire systems should or should not be used? Can three-phase, three-wire, watt-hour meters be used to measure the current consumption in three-phase, four-wire systems? R. L. P.
Pittsburgh, Pa.

ANSWERING the question by R. L. P., the general advantages of a three-phase, four-wire system are as follows:

(1) Increase in the transmitting voltage with the attendant ability to transmit more energy over the same size of conductors without changing the voltage of the transforming equipment. As the energy transmitted varies as the square of the voltage for the same percentage loss, a change from a 2,300-volt, three-wire system to a 4,000-volt, four-wire system would increase the carrying capacity of the same circuit in the proportion of $4{,}000^2 \div 2{,}300^2$ or about three times. As previously stated, no change is needed in the voltage of the transforming equipment, and by changing the connection from delta to star on the side in which the voltage is changed, the desired result is readily obtained.

(2) The ability to ground the neutral point of the four-wire or star-connected side and assure a definite maximum voltage between any transformer winding and ground.

A possible disadvantage of the three-phase, four-wire system may be outlined as follows:

With a grounded neutral, a ground on any of the other lines would result in a short circuit. If the lines were carried through trees or in a conduit

subject to dampness, this would mean frequent interruptions and excessive maintenance. This possible disadvantage, however, is offset by the fact that while this system requires more careful attention, the increased efficiency will result in better operation and less maintenance. As a matter of fact experience indicates that there are fewer troubles with a three-phase, four-wire grounded system than with a straight three-wire ungrounded system, although when the change is made from one to the other there must be a complete and thorough overhauling of the existing system.

The metering of energy on a three-phase, four-wire system can be done as follows:

(1) By using three single-phase meters with three current and three voltage transformers.

(2) By using two single-phase meters or one three-phase, three-wire meter with three current and two voltage transformers.

(3) By using a special three-phase meter with two voltage and three current transformers.

(4) Under exceptionally well balanced circuit conditions, a three-phase, three-wire meter or two single-phase meters with two current and two voltage transformers may be used.

The foregoing methods are all in general use, No. 1 being the most accurate, while Nos. 2 and 3 are very nearly on a par and No. 4 is not at all accurate under any except the most ideal circuit conditions.

The connections for the various methods of metering are shown in the accompanying diagrams, the numbers corresponding with the above paragraph numbers. These connections show the general conventional connections but without regard to any definite polarity. In Fig. 2 a three-phase, three-wire meter is shown, although two single-phase, two-wire meters may be used. The same comment of course is true if two single-phase meters are used.

As a matter of fact, the methods given in Figs. 2 and 3 are very often used.

If R. L. P. is interested further in the matter of metering three-phase, four-wire circuits, he will find valuable information in a bulletin (No. 9, Vol. IX, Bulletin No. 13) issued by Purdue University, Lafayette, Ind., in December, 1925, as a publication of the Engineering Departments.

C. Otto von Dannenberg.
Electrical Division,
General Engineering & Management Corp.,
New York, N. Y.

These diagrams indicate various methods of measuring power in a three-phase, four-wire system.

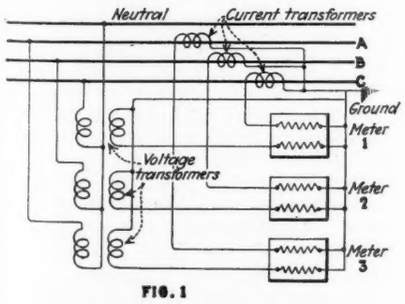


FIG. 1

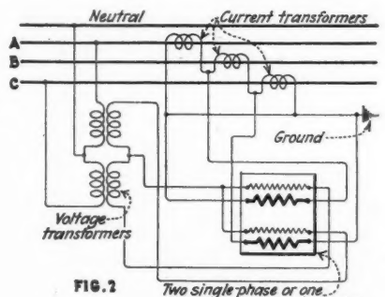


FIG. 2

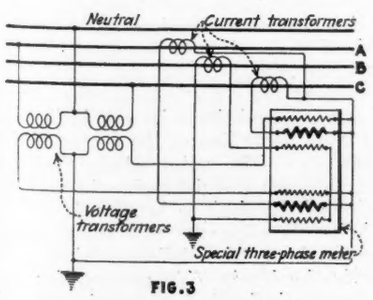


FIG. 3

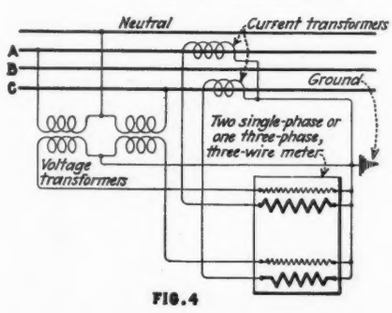
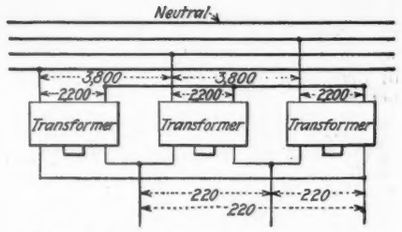


FIG. 4

IN ANSWER to R. L. P.'s question, in a three-phase system two connection schemes are commonly employed; the delta connection, and the star or Y connection. The terminals of a delta-connected system naturally supply a three-wire circuit, whereas the terminals of a star-connected system can supply either a three- or four-wire system, the fourth wire being connected to the neutral point at the center of the Y.

The three-phase, four-wire system has several advantages over other systems. When the load is approximately balanced, power is generally transmitted at 3,800 volts, and the feeder drop is only about one-half of what it would be on a single-phase feeder under similar conditions. The transformers are connected from phase wire to neutral for lighting service, and are star-connected for power service, so that standard 2,200-volt, single-phase transformers may be used for both light and power.

The line construction is no more expensive than for 2,200-volt circuits, although more precaution must be taken to guard against grounding of phase wires, because the neutral wire is grounded and any accidental ground on a phase wire will cause a short circuit. However, a ground on one phase does not interrupt lighting service on the other two phases, as the neutral wire takes up the return current if one phase becomes open.



This diagram shows how transformers are commonly connected to a three-phase four-wire system for 220-volt service lines.

The voltages on the different phases may be regulated independently and an unbalanced load does not interfere with regulation, as the return current is taken care of by the neutral wire. A 3,800-volt, four-wire system with the neutral conductor of the same size as the phase wires requires one-third the weight of copper in feeders that is required by a single-phase or a two-phase, 2,200-volt system, or 44.4 per cent of the weight of copper required for a 2,200-volt, three-phase, three-wire system. Part of this saving in the feeder system, however, is offset by the cost of the fourth wire.

The usual connections for three-phase, three-wire service at 220 volts from 2,200-3,800-volt, four-wire, three-phase mains are shown in the accompanying illustration. Here in order to give the required secondary voltage the primaries are Y-connected and the secondaries are delta-connected.

Energy consumption in a three-phase, four-wire system can be measured by three single-phase watt-hour meters, by a special two-element polyphase meter or by a three-element polyphase meter. Either the first or the third method is used when the phase voltages are badly unbalanced.

Horace Turville.
Lansdale, Pa.

ANSWERING R. L. P.'s question, he should use a three-element meter for a three-phase, four-wire system instead of a two-element meter as used on three-phase, three-wire systems.

In primary distribution this system is usually operated at 3,800 volts between phase wires, and 2,200 volts between any phase wire and neutral. This gives the advantages of 3,800-volt distribution in the feeder system, and permits the distribution of energy over a radius about twice as great as with 2,200-volt transformers. The unbalanced load is carried by the neutral wire, and by the use of line-drop apparatus, good pressure regulation is possible with any proportion of unbalanced load within the rated current limits of the line.

The four-wire distribution mains are carried only where there are motors or large loads to be served; only three wires are needed for installations of

less than 30 to 40 hp., which may be served by two transformers connected in open delta. JOHN W. BANTAU.
Los Angeles, Calif.

REPLYING to R. L. P.'s question, I would say that the advantages of three-phase, four-wire systems are: Greater transmitting distance with the same resistance loss; smaller feeders or conductors can be used, due to a higher primary voltage, which increases line capacity and decreases primary amperage; and standard commercial 20 to 1-ratio transformers can be used.

Usually 4,000 volts are carried on three-phase, four-wire systems, and in cases of mixed and unbalanced loads the three phases and neutral should be used in connecting the transformers, as the neutral compensates for the unbalanced conditions in the feeders of local distribution.

Three-phase, four-wire systems are sometimes used to take care of large power installations that are a considerable distance from the feeding station, but only the three-phase wires are used at the power bank due to the fact that if the neutral is connected to the power bank, and one phase fuse fails, the two transformers would then carry the entire load, in which case they would likely be burned out.

Between this power installation and the station, single-phase, local distribution systems can be connected, using one phase wire and the neutral. One important fact in regard to three-phase, four-wire systems is that at the station there should always be installed one current transformer and one relay in each phase. This will afford safe protection on all three phases of the four-wire system. On three-phase, three-wire circuits usually only two current transformers and two relays are used. If this practice is followed on feeders that supply the four-wire system, the middle phase will be unprotected.

Three-phase, four-wire systems can be metered by using a standard three-phase, two-element watt-hour meter in conjunction with three current transformers and two potential transformers.
Meter Foreman, C. W. ROSELLE.
Illinois Power & Light Corp.
Galva, Ill.

IN REPLY to R. L. P.'s question, the three-phase, four-wire system has the same advantages over the three-phase, three-wire system that the latter has over the single-phase system. Also, there is a saving in copper that is slightly greater between the first two systems than between the latter two.

With the three-phase, four-wire system, two potentials are available. The same potential exists between each phase wire and the neutral, and there is 1.732 times this voltage between phase wires. To make this point more clear, in a three-phase, four-wire circuit having 4,000 volts between each phase wire and neutral, there is 4,000 × 1.732 or 6,928 volts between the phase wires. With this additional potential, a greater transmission radius may be served without undue line drop. For metering, a three-phase watt-meter may be used with three current transformers, and good results can be obtained under all load conditions, providing the potential is constant during any unbalancing in the circuit.

The usual practice is to utilize three single-phase watt-hour meters, connecting one meter in each phase wire, the potential leads being connected between the respective phase wires and the neutral. The sum of the three meters indicates the total energy consumed.

There is also a three-phase, four-wire meter having four series and shunt coils. Two series coils are connected in series for the middle phase wire; the other two series coils are separate, one being connected in each outside phase wire. E. J. ELVISH.
Maintenance Inspector,
Kaministiqua Power Co., Ltd.
Fort William, Ont., Canada.

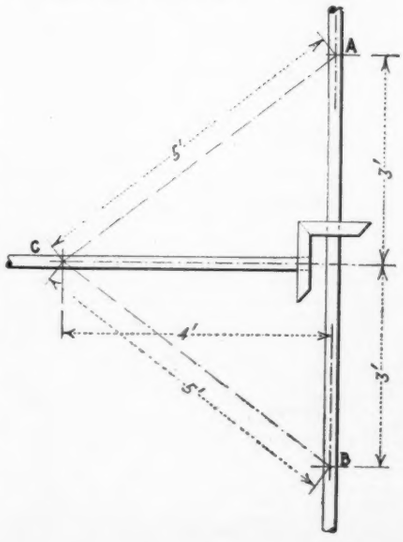
Testing Alignment of Right Angle Shafts

I wish some reader would help me out with some suggestions on a method of testing two shafts mounted at right angles and connected by bevel gears. The short shaft with the bevel gear consists of two 16-ft. sections of 2-7/16-in. shaft. The main 2 11/16-in. shaft is 60 ft. long. I am having trouble due to wear of the bevel gears and think that it is due to misalignment. What is the best way of checking this right angle? Also, how can I be sure that the two shafts are at the same level? E. H. G.
Cleveland, Ohio.

I BELIEVE E. H. G. will find that the old reliable method of checking angles and leveling lineshafts, that is generally referred to as the 3-4-5 or 6-8-10 rule for right angles, and the use of the water level for leveling, will be very satisfactory.

The first step in solving E. H. G.'s problem would be to check the right angle. The accompanying sketch shows how this may be done. The method is the same whether the shaft extends to the right or to the left, or both, as in the sketch. In case the shaft does not extend through, the triangle can be erected at one side only. First, points *A* and *B* are measured 3 ft. from the imaginary intersection, *X*, of shafts. Point *C* is located 4 ft. from *X* at right angles to the main shaft, which has already been measured out a distance of 3 ft. The distance from *C* to *A* or *C* to *B*, or the hypotenuse of the right-angled triangle is exactly 5 ft.; the right angles formed are *A-X-C* and *B-X-C*. If desired, and pulleys do not interfere, the longer dimensions of 6 and 8 ft. with 10-ft. hypotenuse can be substituted for the smaller dimensions. Any multiple of 3, 4, and 5 such as 12 and 16 ft., with 20 ft. hypotenuse, can also be used. The natural result of using longer dimensions is more accuracy if the measuring devices are accurate and the measurements carefully made.

Method of checking a right-angle shaft with bevel gears by the 3-4-5 method of triangulation.



In leveling two lineshafts an ordinary hose filled with water can be used. To make this more convenient and accurate, gage glasses are inserted in the end. The hose should be filled with water, the two ends placed side by side, and the water level marked on each. This will permit much closer readings of the level.
Chief Electrician, E. J. MORRISSEY.
Western United Gas & Electric Co.,
Aurora, Ill.

REFERRING to E. H. G.'s question, the procedure I would advocate requires that first of all two lines be laid off on the floor directly under the shafting. To do this, plumb down to the floor from two points on each shaft.

After doing this, extend the lines drawn through these points until they intersect. From this point of intersection measure off on one line some distance in feet, say 3, 6, or 9 ft., that is a multiple of 3.

Then measure off on the other line from the point of intersection a distance that is 4 times the multiple of 3 used in determining the distance on the first line. Now if the shafts are at right angles the distance between the two points just established should be 5 times the multiple of 3 previously used. If the points are not exactly this distance apart, it will be necessary to alter the alignment of one shaft, selecting, of course, the shaft that is easiest to swing.

In order to establish the new position of the shaft to be moved swing an arc having a radius equal to the distance laid off on the shaft to be moved. While swinging the arc use the old intersection of the shaft lines as the center of one arc, and the point established on the other shaft line as the center of the other arc. The point where the two arcs intersect will determine the new location of the shaft to be moved.

When leveling the two shafts apply the level at two different places, to verify the levels. To account for the difference in levels between the tops of

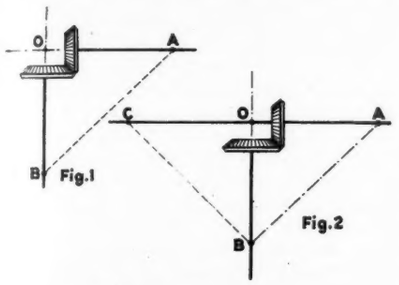
the shafts an allowance of (2-15/16 — 2-3/16) ÷ 2 = ⅛ in. must be made at the smaller shaft.

Trouble with bevel gears may come from their not being properly meshed, either in depth or endwise. Also loose collars or poorly braced hangers, which allow the teeth to force the gears apart under load, may cause trouble.

Plant Engineer, H. D. FISHER.
New Haven Pulp & Board Co.,
New Haven, Conn.

IN REPLY to the question by E. H. G., I find it best to check the shafts first with a good spirit level before proceeding to check the angle between the shafts.

One method of determining the right angle between two shafts involves the



These diagrams indicate the respective positions of points to be used in checking a right angle between shafts.

Pythagorean theorem, that the sum of the squares of two sides of a right angled triangle is equal to the square of the hypotenuse. Thus, the method of procedure, as outlined in Fig. 1 in the accompanying illustration, is as follows: According to the above theorem $(OA)^2 + (OB)^2 = (AB)^2$. The point O is where the shafts through the two gears would meet if they were extended. Points B and A should be marked with a center punch on the top center line of each shaft. For example, suppose OB is laid off 100 in. and OA is 120 in. Then $BA = \sqrt{(100)^2 + (120)^2} = \sqrt{10{,}000 + 14{,}400} = 156.25$ in., approximately. These dimensions must be carefully laid off with a wire or steel tape, something that will not stretch.

In the second case, as illustrated in Fig. 2, no calculations are necessary. Proceed by marking the point O where the center line of both shafts would meet if the shaft marked by point B were extended. Then mark points C and A making $CO = AO$, or about 6 ft. If the two shafts are at right angles, CB must exactly equal AB.

R. B. TURNER.
Manager,
Johnson-Turner Electric Repair & Engineering Co.,
Walkerville, Ont., Canada.

REPLYING to the question by E. H. G., the right angle between two shafts can be checked by measuring the distance between two points, one on each shaft, each point being determined by measuring off a certain distance from the point that would be established if the shafts were extended so that they intersected. The distances laid off on the shafts can be called the legs of a right-angled triangle. The length of the hypotenuse or distance between the two points established on the shafts can be determined by recalling the old rule of 6-8-10, where 6 and 8 represent the legs of the triangle and 10 the hypotenuse, or the distance between the two points established on the shafts.

As the shafts are not of the same diameter, an allowance must be made at the smaller shaft when using a level between the two shafts. That is, an allowance of (2-15/16 — 2-3/16) ÷ 2 = ⅛ in. should be added to the top of the smaller shaft. E. N. DILLARD.

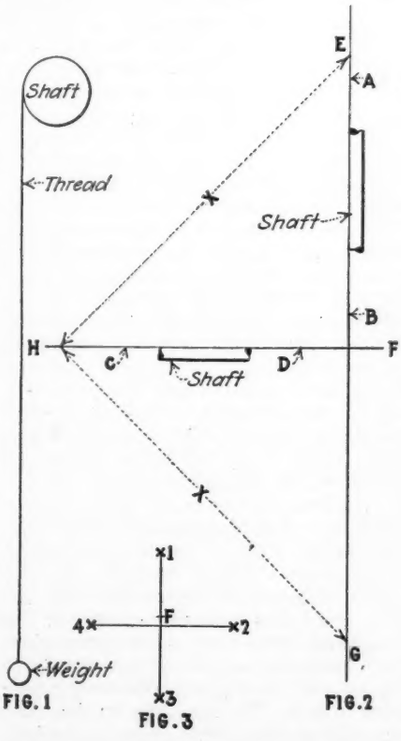
Chief Electrician,
Booth Kelley Co.,
Springfield, Ore.

ANSWERING E. H. G., he will find that a good, practical method whereby right-angle shafts may be accurately aligned is as follows: Suspend plumb bobs or weights from fine silk threads over the shaft as shown in Fig. 1 at points A and B, or at similar convenient points along the line EG, in Fig. 2. When the plumb bobs have ceased swinging establish a horizontal silk thread line AG, so that the horizontal thread just touches the vertical threads A and B.

Similarly, drop silk threads from the shaft at right angles with the first at points C and D and establish a second horizontal silk line HF. From the point of intersection F measure off convenient distances FE and FG, both of which must be exactly equal. Then from an equal or almost equal distance HF, measure the distances HE and HG. If HE is exactly equal to HG the shafts are at right angles. The reason why, I believe, is perfectly obvious.

The light, silken threads will deflect somewhat even though pulled taut. The horizontal silk lines should be perfectly horizontal, and on the same level. This may be accomplished so that the measurements will be accurate by locating the suspension points at equal distances from the point of intersection F as shown in Fig. 3. Point F in Fig. 3 is the same F as in Fig. 2, but Fig. 3 is drawn to a much smaller scale to show the suspension points. Thus, $1F$, $2F$, $3F$, and $4F$ are all equal in length; hence the deflections of each will be the same with the same tension in both threads.

Figs. 1, 2 and 3—Method of checking alignment of right-angle shafts by triangulation and the use of plumb bobs.



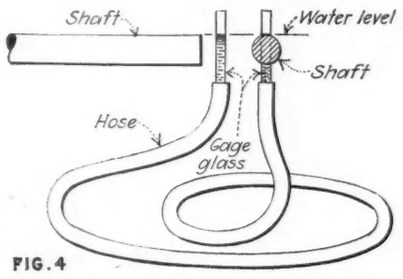


Fig. 4—Use of water level in checking level of shafts.

This level, which consists of a hose and two pieces of gage glass, can be used to level each shaft after the right angle is established, and also to check whether the two shafts are in the same horizontal plane.

There are a number of good ways in which right-angle shafting may be leveled accurately. One way involves the use of an ordinary garden hose filled with water, with gage glasses inserted in the ends as indicated in Fig. 4. No matter how far the ends of the hose are apart, the water will always assume a perfect level and the observer can make sure that the shafting is absolutely level at all points. This method is useful not only for leveling shafting but for laying foundations for machines and buildings, and even for laying large floors.

When employing the hose method the millwright must be certain that there is no air in the hose and also make sure that one end of the hose, after filling with water, is not heated to a higher temperature than the other end. It is evident that an air pocket will cause a false level; also, if one end is heated, the density of the water in that end will be less and consequently the level will be higher.

The best method of all, when leveling and aligning shafting, is, I believe, to use a special adaptation of surveyor's instruments that are on the market for that purpose. However, these instruments are rather expensive for small plants that do not have much shafting

to align. For small jobs the method outlined herein will be found perfectly satisfactory when done with care, and it can be done quickly.

W. F. SCHAPHORST.

Mechanical Engineer,
Newark, N. J.

Effect of Commutating Poles on Magnetic Field

I have noticed that some of our d.c. interpole machines are equipped with one commutating pole per pair of main poles, while others have one commutating pole for each main pole. In cases where one commutating pole is used per pair of main poles, is there any unbalancing in the magnetic field that will cause cross armature currents? Readers' opinions will be appreciated. W. M. P.
Seattle, Wash.

ANSWERING W. M. P.'s question, the object of using interpoles is to reduce sparking at the brushes. This is accomplished by providing an auxiliary flux or commutating field at the point where the armature coils are short-circuited by the brushes. The action of this commutating field is to help resist the current in each coil while it is short circuited by the brushes, thus reducing sparking.

The interpoles produce a magnetic field, which in turn causes the current in the field coil under commutation to reverse and build up in the opposite direction. If the field in this case is too weak, the reversal will occur too late, and there will be sparking. If it is too strong, the reversal will come too early, with the result that the current will then build up too high and will have to be suddenly reduced as the commutator bars pass out from under the brush. Under this condition, there will also be sparking.

Each interpole on generators should have the same polarity as the pole that trails it, in respect to the direction of armature rotation, but in motors the interpoles should take the polarity of the pole that precedes them. If the machine has four main poles, it will still operate satisfactorily with only two interpoles.

For a wave-wound armature, it is not necessary to use more than two brushes, regardless of the number of poles used, but generally it is advisable to use more than two brush positions with wave windings, especially when the current is very large. H. J. ACHEE.

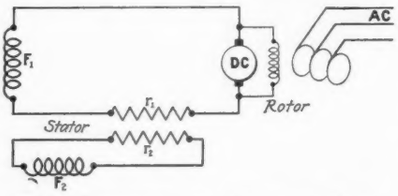
Superintendent,
City Water & Light Dept.,
Woodward, Okla.

Characteristics of Fynn Weichsel Motor

I shall appreciate it if some reader will explain in non-technical terms the characteristics, construction, and principles on which the Fynn-Weichsel motor operates. Is it necessary to use special control equipment with this motor?
Lansdale, Pa. H. T.

ANSWERING the question by H. T., the Fynn-Weichsel motor is a synchronous-type motor in so far as its operating characteristics are concerned. When the motor is operating in synchronism, the power factor is leading and the amount of leading power factor depends, of course, upon the amount of excitation supplied to the motor. The operation and characteristics of the motor are best explained by referring to the accompanying diagram.

In this it will be seen that the rotor carries three slip rings, and also a direct-current commutator. The primary alternating-current power at 220, 440 or 550 volts is applied to the slip rings. The stator consists of two phases of windings that are wound 90 electrical deg. apart, and distributed around the circumference of the stator. One of the stator windings, F_1, is connected permanently in series with the brushes that take off direct current from the commutator of the rotor. Incidentally, the amount of direct-current power is about four per cent of the total power imput to the motor, and, of course, is very



This diagram shows the connections of the windings of a Fynn-Weichsel motor.

small. The other winding, F_2, which is wound 90 electrical deg. from winding F_1 is short circuited upon itself when the motor is operating in synchronism. This is accomplished by means of a simple resistance-type starter that short circuits the resistance r_1 and r_2.

When the motor is started, all resistance is in each of these two circuits, in series. As the handle of the starter is moved over, the resistance is cut out until finally winding F_1 is in series with the d.c. commutator, and winding F_2 is directly short circuited upon itself. Of course, the direct-current winding supplies alternating current until the motor reaches synchronous speed. The frequency of the current, however, is decreasing as the speed of the rotor increases. When the slip has become very small, the direct-current commutator is carrying a very low frequency of alternating current, approximately two or three cycles per second. This low frequency alternating current assists the motor in pulling into step, or synchronizing itself, after which the current is direct current only. Winding F_2 then acts as a damper winding, and prevents the rotor from oscillating back and forth, which is called hunting.

The construction of the motor is very similar to that of a slip-ring motor with the addition of a small commutator, usually on the end opposite the slip rings, although on the smaller sizes the slip rings and commutator are on the same end of the rotor. The stator windings are quite simple, consisting of two series windings with the concentric-pole type of coil. The windings on the rotor are the regular three-phase a.c. windings, together with the small, direct-current windings used for exciting purposes.

The control equipment furnished with Fynn-Weichsel motors consists of the primary magnetic switch, which is equipped with undervoltage and overload protective devices. This switch is interlocked with a simple resistance starter that is inserted in the secondary circuit, F_1 and F_2. The operation of the motor consists in moving only one control handle from the start position to the run position. This handle has contacts interlocked with the primary magnetic switch that closes on the first step; the remaining steps cut out the resistance in the secondary circuit, bringing the motor up to speed.

This motor has power-factor corrective capacity, and is installed primarily for the purpose of raising the power factor of industrial plants. The motor may be used on any constant-speed drive, provided operating conditions are such that the application is justified. It is always best to use these motors where the service is continuous for long periods, such as air compressors, line-shafts, blowers and other drives of similar nature. Since the motor has slip-ring starting characteristics due to the resistance in the secondary circuit at start, it can be used on loads requiring a high torque to start. Furthermore, it is often possible to use smaller motors of this type than the regular squirrel-cage induction motor, as the torque of the latter type is very low compared with the slip-ring type, which is practically identical with the Fynn-Weichsel.

JAMES B. HOLSTON.

Commercial Engineer,
Wagner Electric Corporation,
Chicago, Ill.

IN ANSWER to the question by H. T., the Fynn-Weichsel motor operates as a slip-ring induction motor at synchronous speed. It starts as a slip-ring induction motor, and has much better starting characteristics than the usual squirrel-cage motor; that is, it will develop 150 per cent torque with a starting current of 150 to 200 per cent of full-load current. After the motor attains synchronous speed, which it will do easily with a 150 per cent load, it becomes an over-excited synchronous induction motor, the excitation varying with the load. With appropriate windings, the motor can be made to operate at unity power factor or with a definite leading current to compensate for the lagging current taken by other motors on the same line.

As a synchronous induction motor, the Fynn-Weichsel motor will carry 150 per cent load without falling out of step. Above this value it takes on induction motor characteristics and continues to run as a slip-ring motor to the breakdown point of approximately 300 per cent load before it stops.

This motor combines the favorable and desirable characteristics of both slip-ring induction and synchronous motors, and yet possesses none of their most objectionable features.

Loading this motor beyond the limits

of the synchronous speed operation simply establishes slip sufficient to carry the load as an induction motor. There is always a synchronizing tendency that reduces the slip and when the load decreases to a point below 150 per cent of full load, it pulls the rotor back into synchronism. The value of this characteristic is very important, as it enables the motor to carry temporary excess overloads in the same way that the squirrel-cage or slip-ring induction motors will carry overloads, thereby making the motor just as stable and practical in its operation as present types of induction motors. However, the chief value of this motor lies in the fact that it can be used for power factor correction.

The Fynn-Weichsel motor is connected to an a.c. controller in practically the same way as any slip-ring motor.

Electrical Engineer, WM. MCGUIRE.
Carbondale Machine Co.,
Carbondale, Pa.

IN REPLY to H. T., the rotor of a Fynn-Weichsel motor is provided with a commutator and slip rings. There are two windings on the rotor: one is a direct-current winding, which is connected to the commutator, and the other is a regular three-phase winding connected to the slip rings, which are connected to the line.

The stator also carries two windings. One is the main direct-current field winding; the other is an auxiliary winding, placed 90 electrical deg. apart. The special control equipment that is necessary, which includes a faceplate starter having two resistors, one for each of the stator windings, usually comes with the motor.

In starting a Fynn-Weichsel motor, the line switch is closed and the handle of the faceplate starter moved from the off to the running position, which operation should take about 15 sec. During this process a resistance is connected in the main winding and also in the auxiliary winding. This gives the motor a starting performance similar to that of a slip-ring induction motor. The resistance is gradually cut out until finally the running position is reached. when the auxiliary resistance is cut out altogether and carries no current, and the resistance is also cut out of the main winding. The main field winding receives its direct current from the commutated rotor circuit.

Fynn-Weichsel motors are ordinarily connected for clockwise rotation, but should it be necessary to change the direction of rotation, change two wires on the slip rings and move the rocker arm from right to left or in the reverse direction, as the case may be. The direction of rotation of the motor should correspond with the direction indicated on the rocker arm.

The starting characteristics of a Fynn-Weichsel motor are similar to those of a slip-ring induction motor. In addition a Fynn-Weichsel motor will draw only 150 to 200 per cent of its full-load current when the starting torque of this motor is 150 per cent of the full-load torque. Now, immediately after the motor comes up to synchronous speed, it becomes a self-excited, synchronous-induction motor. At normal load the motor operates at leading power factor, thereby compensating to a certain extent for the lagging current taken by other induction motors on the line. This motor operates as a synchronous induction motor up to 150 per cent of full-load torque; on heavier loads it operates as an induction motor. W. R. WOLFE.
Vancouver, B. C.

IN ANSWER to the question by H. T. the Fynn-Weichsel motor is a synchronous-induction motor. It operates as a synchronous motor from the time it reaches synchronous speed and can correct the power factor of other induction motors on the line until a heavy overload causes its speed to be reduced. Then it assumes the speed, power factor and losses of an induction motor.

The main operating current enters the rotor through brushes and slip rings. Besides the rotor winding, the shaft carries a small direct-current winding and the necessary commutator and brush rigging for current collection.

The stator windings are in two parts, being displaced 90 electrical deg. from each other. One of them is supplied with the direct current generated by the small winding on the rotor and the other is complete it itself, except during the starting period when both stator windings have variable resistances cut in series with them by the starting controller.

In brief, the Fynn-Weichsel motor is essentially an induction motor up to the point where the direct current acting on one stator winding helps to pull the motor into synchronism with the operating current; after this its characteristics are those of a synchronous motor.

In operation, the power factor is leading until the torque demand on the motor reaches approximately 150 per cent of full-load torque. If the torque load is increased beyond this point, the motor drops out of synchronism and assumes induction motor characteristics with such good overload capacity that it will not pull out or stall until approximately 300 per cent of full-load torque is reached. On the other hand, if the torque does not reach the pull-out stage but decreases instead, the motor begins to approach synchronism again and will actually attain it if the torque drops to 150 per cent of its full-load rating.

If there are other motors in the installation, the Fynn-Weichsel motor will ordinarily be able to supply leading current for correcting the power factor of the plant.

These motors are available in sizes from five to several hundred horsepower and are featured in three-phase types, but there does not seem to be any reason to doubt that two-phase motors of this type could be just as easily manufactured. In general appearance this motor resembles a wound-rotor induction motor and has an equally good starting torque. For starting purposes the controller is equally simple.

This motor costs more than either a squirrel-cage or wound-rotor motor of the same speed and horsepower; hence the only reason for using it will be on account of its ability to correct power factor and no doubt there are many plants where it is the answer to the power factor problem. On the other hand, as it is newer on the market than either a synchronous motor or a static condenser, time will be well spent in making a thorough study of these three methods of correcting power factor before any decision is made.

Vancouver, B. C. L. E. DUNHAM.

REPLYING to H. T.'s question, the Fynn-Weichsel motor has its primary winding on the rotor and receives its power current through slip rings on the rotor shaft. The excitation of the motor is supplied from an auxiliary winding through a commutator on the same shaft, and standard type slip-ring starting equipment is employed.

The motor starts with the characteristics of a slip-ring induction motor and operates as a synchronous motor under normal load conditions, but automatically becomes an induction motor if pulled out of synchronism by an excessive overload. When the overload has been sufficiently reduced, the motor automatically pulls back into step as a synchronous motor.

The power factor of the motor, depending, of course, upon the amount of excitation, is unity or leading at full load. These motors have a high starting, accelerating, and pull-in torque, and also ability to carry heavy overloads. PERCY LAMOTHE.
Smooth Rock Falls, Ont.

WITH reference to the inquiry by H. T., Fynn-Weichsel motors are designed for general use and embody the characteristics of two types of ordinary, well-known motors that have been on the market for a number of years: the standard slip-ring induction motor and the synchronous motor.

Compared with the induction slip-ring motor, the Fynn-Weichsel motor has very high starting torque, is power factor corrective, and is able to stand heavy overloads or highly fluctuating loads without an appreciable change in speed. As compared with the ordinary synchronous motor, it has a much higher starting torque, does not require a separate source of direct current for field excitation, and is not so likely to pull out of step when a heavy, momentary overload comes on.

The construction of these motors differs widely from that of the induction or synchronous motor. The rotor is provided with a set of slip rings and a commutator and has two separate windings in the slots, one above the other. In the bottom of the slots is the d.c. winding that is connected to the commutator. The standard polyphase winding, connected to the slip rings, is in the top of the slots.

The rotor of a Fynn-Weichsel motor might be compared to an armature from a d.c. generator that is so con-

structed that the commutator is at one end of the shaft and a set of rings, which are connected for compensating purposes to the armature, placed at the other end of the shaft. The stator resembles an ordinary induction motor stator except that it has two separate windings. These two windings are known as the main d.c. field winding and the auxiliary winding. These windings are displaced 90 electrical deg. from each other.

Under normal running conditions the d.c. field winding in the stator is connected in series with the brushes on either side of the commutator. The stator auxiliary winding is short circuited and the power source is connected to the slip rings. When starting, resistance is in circuit with both windings of the stator, and as soon as the motor comes up to speed, throwing the starter from the starting to the running position completes the connections, as outlined above. Under these conditions the motor has the main field winding automatically supplied with direct current from the rotor through the commutator.

A few words might be said in regard to changing the rotation of these motors. On ordinary induction motors it is, of course, only necessary to reverse two of the motor leads, but with a Fynn-Weichsel motor it is also necessary to shift the rocker arm carrying the commutator brushes. These rocker arms are all carefully marked for their two positions, giving clockwise and counter-clockwise rotation of the rotor. The reason for changing the rocker arm is to cause the machine to generate direct current after its rotation is changed.

The question of starting equipment is not one to cause much difficulty even though it requires a little extra equipment. H. T. might use ordinary starting compensators by adding the two resistances and a means of cutting out these resistors when the motor is running full speed or the starter is in the running position. The standard starters for these motors are no more complicated than a regular compensator or the starting equipment for a slip-ring induction motor, and they are much more simple than the starting equipment for a synchronous motor in spite of the fact that such starters are now made entirely automatic; simply pushing a button starts or stops them when required.

There are many applications for Fynn-Weichsel motors and the following is a general idea of applications rather than a long discussion of unimportant details. They should be used where constant speed is required or on jobs requiring a high starting torque. Then, in cases where an induction motor would be running idle a large part of the time, these motors may be applied to secure the advantage of their power factor corrective ability. In locating these motors in damp or dusty places or where they will be subjected to acid fumes, much care must be taken to see that they are properly protected. It is best with this type of a motor to apply it where it will be clean, dry and away from dangerous fumes.

These motors are generally far too expensive to be applied for power factor correction alone, but when used around an industrial plant with other motors they will boost the power factor enough to make a material saving, because the nearer a plant runs at unity power factor the less the copper losses in transformer and distribution lines will be. The Wagner Electric Corporation manufactures this motor, and will, no doubt, be glad to furnish any other information desired.

Donnacona, Que. LEE F. DANN.

Best Kind of Insulation for Semi-Closed Slot Motors

I shall appreciate it very much if readers will tell me whether it is better practice to use varnished cambric between the coils in a semi-closed slot motor, thereby insulating each coil from its neighbor, or to tape each coil separately and then use insulation only between phases.
Rome, Ga. M. S. C.

IN REPLY to the question by M. S. C., the choice of insulation is largely a matter of opinion, governed by operating conditions. For motors operating in damp places and in places where they are subjected to acid fumes, I have found that the following method gives excellent results:

We use Armco fiber paper for slot liners in all of our motors, and in the semi-closed-slot motors one thickness of paper is used in the slot for each coil; that is, a liner is placed in the bottom of the slot and then a paper liner that comes up to the top edge of the slot. When inserting the second coil in the slot another liner of paper is put in, which insulates the coils from each other.

This Armco paper is very tough. It will withstand much binding before it breaks, and will not tear easily at the end of the slots where the coils pull sidewise against the paper. This paper can be obtained in sheets of various sizes and various thicknesses. For all our work on 550-volt motors, we use 10- and 15-mil paper. In the semi-closed-slot motors we use two thicknesses of the 10-mil size, and in open slot motors one thickness of 15-mil paper is used.

We believe that the proper treatment of the coils before they are installed in the motors really has more to do with the operating life of the motor than the slot liners. On page 95 of the February, 1927, issue of INDUSTRIAL ENGINEER, there is an article on the preparation of coils for semi-closed-slot motors. The results we have obtained with coils treated in the manner described in that article have been incomparable. I have actually seen some of our motors started up with water dripping from every part. This happens regularly in two or three very damp places around the mill and up until the time we rewound semi-closed-slot motors in the manner described in that article, we experienced trouble from short-circuited and grounded coils. Personally, I believe any paper that is tough, non-porous and of average texture and thickness suitable for coil slots. L. F. D.

REPLYING to the question by M. S. C., the usual practice in contract shops is to tape the knuckles of coils about 1 in. each way with half-lapped cotton tape, this tape being about 0.007 in. thick and 0.75 in. wide. The coils are then wound without dipping, phase insulation being inserted as the coils are wound. Naturally many different shops have their individual ideas concerning the amount of insulation required. Some use one thickness of 0.01-in. varnished cambric between phases for 600 volts or below; others use two thicknesses, and still others, three. Only a few shops, with whose methods I am personally acquainted, use phase coils. These phase coils are usually placed in open-slot motors, and in this case it is a good plan to use canvas strip doubled between the top and bottom halves of coils where they project out of the slot.

On 2,300-volt equipment closed-slot coils are usually taped up to the slot, even if this has to be done after the coils are placed in the slots. This type of motor is not very popular and I am sure that the open slot for this voltage will entirely replace it, as the more modern motors for this voltage seldom use closed or semi-closed slots.

Several manufacturers are tying their coils, especially on the smaller sizes, and inserting empire cloth or varnished cambric between the coils. Personally, I believe that this gives a safer winding for low voltage than does taping at the knuckle and inserting phase insulation. If this method is used, I believe it would be a good plan to use double the amount of insulation between phases. Even though taping is discontinued, the sleeves should be put on the coil leads just the same, in which case spaghetti tubing could be used on the jumpers, thus saving time in connecting up the motors.

If the jumpers are taped, two layers of half-lapped cotton tape, or one layer of cotton and one of varnish cambric, can be used for voltages below 600. On 2,300-volt motors some shops prefer to use two layers of varnished cambric and one of cotton; others use one layer each. On 220-volt motors, sleeving dipped in air-drying varnish and then dried can be used instead of tape.

Contract shops almost always put in as much insulation in the slot as the space allows. Seldom are less than two 0.01-in. fishpapers used with 0.010-in. varnished cloth sandwiched in between. In winding semi-closed-slot motors, 0.015-in. or thicker paper is used, if there is plenty of room next to the coil. The stiffness of the paper will tend to hold it close to the slot wall and will prevent the paper from crimping at the corners when the coil is inserted. This is an advantage in stators with narrow slots.

It is a good plan to use cotton-covered, enameled wire, if space is limited. Al-

ways use either double-cotton or cotton and enameled wire in closed-slot motors; single-cotton-covered wire is seldom sufficient.

Cotton tape will stand about 100 volts per mil; double cotton covered about 150 volts; mica, 800 volts; varnished cloth, 750 volts; and fishpaper, 250 volts. These materials have a capacity increase of 100 per cent when impregnated and baked with a reliable varnish.

The factor for insulation that is generally used is 70 volts per mil for an a.c. machine and is calculated for the terminal voltage of the machine. However, for a 220-volt machine this would be only about 3 mils, which is not mechanically strong enough to allow for the insertion of coils and resultant handling. So, for mechanical reasons this rule cannot be applied to low-voltage machines and various papers are used in connection with Micanite and empire cloth. These papers constitute fair insulation when dry, but if moisture is present their insulating value is very low; hence the necessity for baking completed windings before dipping. This baking drives out the moisture and also the air, which allows the varnish to penetrate more readily.

GRADY H. EMERSON.
Birmingham, Ala.

ANSWERING M. S. C.'s question, at our plant after the coils are wound into the form of a loop, they are heated to a moderate temperature and dipped in a very thin solution of insulating varnish. We allow the coils to soak in the varnish, while still warm, until completely filled or saturated. When all signs of air bubbles have disappeared, the coils are withdrawn from the varnish container and hung up to drain off the excess varnish. When the draining-off process is finished, the coils are removed to a warm place and left hanging up until they have thoroughly air dried. The time required to dry the coils properly is about 24 hr. The coils are now ready to be spread. After this is done the ends of the loop are then wound with linen tape for a short distance, nearly up to where they rest in the slots.

Before placing the coils in the slots, the turns are given a coating of parowax. This gives the coils a nice, smooth surface and makes it much easier to pass the turns through the openings in the slots. It is a well-known fact that an application of parowax is beneficial on all winding jobs and most winders make use of it extensively.

I would recommend the following for slot insulation for 220-volt machines when a heavy thickness of fishpaper is used to cover the whole slot: Use a layer of varnished cambric, letting it protrude, say, about 1½ in. above the slot so as to act as a guide for the turns of the coil. After the bottom layer of the coil is in place, cut off the varnished cambric even with the top of the slot, ramming the ends down in the slot so as to envelop the coils. If there is enough space, you may add a strip of fiber between the bottom and top layers of the coils; it is a very good plan to also put a strip of fiber in the very bottom of the slot.

For the top layer, lay another piece of varnished cambric in the slots the same as for the bottom layer and then proceed as with the bottom layer, finishing the slot by driving in the retaining fiber wedge. When all the coils are assembled in place, heat the whole motor to a moderate temperature. Dip the whole motor in warm baking varnish, allowing it to soak well until saturated. Then allow it to drip for about one hour before putting it in the baking oven.

H. J. ACHEE.
Superintendent,
City Water & Light Dept.,
Woodward, Okla.

IN ANSWER to the question by M. S. C., the first method which I will describe for insulating semi-closed-slot motors has proved very satisfactory at our plant, some of the motors being 20 years old. After trying many methods of insulating motors, I have found it best to mold 0.010-in. No. 1 Micanite plate for slot insulation, winding the coils in groups to eliminate soldered connections and insulating each coil with 0.007-in. Armco paper and 0.015-in. oiled cambric between phases. Then dip the motor, after heating it to 80 or 90 deg. C., in General Electric No. 460 baking varnish. Two dippings in this varnish should be made, thoroughly baking after each dip.

Then I apply No. 8 Bakelite compound as a paste to the whole winding. This gives a thoroughly oil- and moisture-proof insulation. Some of these motors have run under water that was not very pure with no apparent ill effects. The Bakelite, however, requires some skill in applying and baking. For instance, it is necessary to moisten the hands in kerosene to keep the Bakelite from sticking to them, as there is no solvent that I have found that will remove it. Although it can be applied with a paddle or putty knife, it is best to apply it with the hands, so as to force it thoroughly into all the crevices in the winding.

However, if you do not care to use Bakelite or some other sealing compound, of which there are many on the market, taping and then baking each coil is the best method, although I have found it cheaper to use the above procedure. For instance, I have stripped, wound, baked, and had running in 21 hr. a 20-hp., G.E., 1,200-r.p.m., three-phase, 60-cycle, 440-volt, 50-deg. motor. My efforts resulted in a first-class job both in looks and durability. Winding the motor was a small job, taking in all about 6 hr. for two men, this time including that required for making the connections. Consequently, I have now standardized on mica insulation for all semi-closed-slot motors and wound rotors, the rotors being a complete mica job, as no other insulation is used.

Some of these motors have been running for three years, direct-connected, and I have not had a failure except in one case where we baked the Bakelite too fast. This material must be held at 60 to 65 deg. C., a slow heat being necessary to prevent blistering. Many of our motors operate months at a time, without even stopping, at an operating temperature of 80 to 90 deg. C., while before using the present method we rewound on the average one motor a month, as there are fourteen motors of this size and type in our plant.

For bearings, we use Stewart bronze, which has been considerably more satisfactory than babbitt. During the past three years our monthly motor inspection report shows that our bearings have worn less than 0.002 in.

R. I. FROST.
Chief Electrician,
National Cement Co.,
Ragland, Ala.

IN ANSWER to the question by M. S. C., I would strongly advise taping each coil throughout with Linotape; then over this wind a layer of cotton tape. After this is done there is no necessity for additional insulation between the phases, as there will be at least two thicknesses of Linotape between the coils. Taping the coils throughout with Linotape also makes them practically moisture-proof, lessening the chance of internal shorts in coils caused by dampness or fumes.

I have found that insulation placed between phases often becomes loosened and dislodged by vibration, thus leaving only cotton tape between the coils; in such cases a breakdown in the insulation usually results.

The cost of insulating coils in this way is very little higher than other methods. Personally, I have used this method for over six years on motors that are operating under very severe conditions and have had very little trouble.

C. MCCOLLUM.
Chief Electrician,
Gunns, Ltd.,
West Toronto, Canada.

IN ANSWER to M. S. C., I believe he will find the standard practice used in our shop to be a very efficient method of insulating the coils in semi-closed slots. We take 25- or 30-mil Armco paper and cut separators. After one coil is inserted in the slot, the paper is cut as wide as the slot on top of the first coil, and then it is placed between the two coils.

The coils are taped on the ends only, thereby allowing the winder to separate the ends or turns to be put in the slots. If it is desired to tape the coils fully, this will have to be done after the coil has been inserted, but it takes more time than our method.

To get the correct width of the separator, cut a piece of Armco paper, 25 mils in thickness, to the shape of the wedge. Insert the narrow end in the slot from one end, and mark it just where it touches both sides. The separator should be neither too narrow nor too wide, for if too wide it will fold on the sides and if too narrow it has a tendency to turn. M. S. C. could then use varnished cambric between the phases.

J. M. PETERSON.
Troy, N. Y.

Electrical Service

AROUND THE WORKS

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Hoist Trouble Encountered While Repairing Ammonia Purifier

FOLLOWING in line with our perpetual campaign of Safety First, the writer eliminated a hazard that could have easily caused a serious accident, both to workmen and equipment. On the evening that the armature of a hoist motor, which had burned out, was being installed, trouble was encountered in the form of a leak up near the top of the ammonia purifier, which is located in a six-story building and reaches from the bottom to the top floor.

In order to locate the trouble it was necessary to remove the cover and top ring of the purifier and lower them to the ground floor. This work was done by means of a monorail electric hoist located overhead, and a set of rails for moving the hoist over the different machines or stills.

The hoist is manipulated by hand chains at one end of the bridge or monorail, and the motor, which is geared to a drum having enough cable to reach the ground floor, is controlled by a standard G-2 faceplate type controller, mounted directly on the side of the hoist. The controller is actuated by hand ropes with suitable wood handles connected to each end of the controller arm and within reach of the operator.

After the cover of the purifier had been removed and lowered to the ground floor, the hook was hoisted again to the top of the machine to remove the top ring. Then the operator left the controller and started maneuvering the hoist over the still. At this time the operator had unknowingly opened the controller with the result, to my amazement, that the block and hook, which were but 1 or 2 ft. from the top limit of their travel, suddenly moved upward at full speed directly over the heads of the workmen. Realizing there was no limit switch on the hoist, and that the line switch was on the floor below, I climbed from my position on top of the machine next to the one being repaired, which is three rings higher, to a position just over the side, where I discovered the rope on the hoist side of the controller arm was fouled between a pipe flange and a projecting bolt. It was but the work of a moment to kick the rope free, but not soon enough to keep the block from jamming and badly straining the cables.

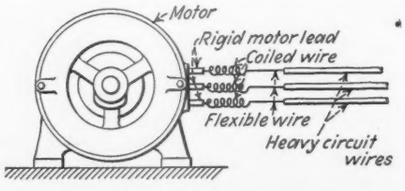
Very fortunately, however, no one was injured. Needless to say, I immediately started to plan the removal of the controller from the hoist, and after considering several plans, decided on mounting it on the wall overhead and in front of the shaft. I also brought the line switch up and mounted it at a point about 4 ft. above the floor where the operator stands, and beneath and just a little to one side of the controller.

A. L. BINGHAM.

Chief Electrician,
The Ironton By-Product Coke Co.,
Ironton, O.

Rigid Leads Cause Three-Phase Motor to Run Single Phase

ONE job, which I had occasion to service, was located out in the country. The motor that was giving trouble was arranged so that it would swing while driving a circular saw. It had evidently been running single phase, for they told me that they used to pull the belt to start it, but when at last this method failed, they, of course, found it necessary to call in a service man.



This shows how a motor may be connected to safeguard against the breaking of the lead wires within the motor.

When I opened the motor I found it full of dirt and the leads were all broken loose from the terminals by the constant straining back and forth with rigid connections. Whoever wired up the job did not use flexible cable to connect the motor terminals to the line. As these leads were rigid, the terminal wires inside the motor gave out first, being the weakest point in the line.

The method of repair that I adopted was to supply the motor with flexible leads so that there would be no more straining on the line, especially inside the motor, in the future. I connected one end of a coiled wire to the motor terminals within the machine and braced it securely to the frame so that no motion of the conductor would occur within the motor. After connecting the flexible wires between the coil wires and the heavy circuit wires, the job was completed as indicated in the accompanying illustration. Although this job was supposed to be a temporary one, it was rendering satisfactory service the last I heard of it.

E. J. MORRISSEY.

Chief Electrician,
Western United Gas & Electric Co.,
Aurora, Ill.

Isolated Substation Improves Operating Conditions in Coal Mine

IN THE coal-mining industry, the distance from the pit mouth back to the working face may be several miles, and for every ton of coal mined this working face advances farther from the mine mouth. The substation that supplies power for work underground is usually located at either the mine opening or ventilating shaft, which is a considerable distance from the load center.

The effect of the long lines that must be run to carry d.c. power to the workmen and machines underground is quite often shown in the decreased production which results from insufficient voltage at the working face. Motors working at reduced voltage may have frequent armature burn-outs, even though they may be operating at far less than their rated capacity. At the present time, when mining costs must be held at a minimum, the question of better voltage regulation is a vital one to the operating department.

We found that voltage regulation was poor at our mine shortly after production started, the entire output of which is consumed at our steel mill power house.

We expected to transmit d.c. power from the mill substation, a distance of about 1¼ miles, at 275 volts, but we found it would be impossible to maintain proper voltage later on because of the rather rapid advancement of the working face.

Accordingly, we built a 2,300-volt, three-phase, 60-cycle line from the mill power plant, a distance of about 2 miles, and located a substation on the surface at the approximate center of the future workings, where we installed a Ridgway motor-generator set with General Electric automatic-reclosing d.c. circuit breakers. The d.c. cables were run through a bore hole to the mine workings underground.

As this automatic substation is isolated and unattended, it was quite important that it should be protected against abnormal conditions; so protection was provided against overloads in the d.c. line and in the a.c. circuit. The synchronous motor starting equipment is manually operated and provided with overload and undervoltage protection. Bearing relays are installed on the motor-generator set, so that in case of a hot bearing the set is shut down and if an overload opens the synchronous-motor circuit, an attendant must go to the station to determine the trouble and restart the set.

Some of the advantages to be had from an installation of this kind are good voltage at the working face, no labor cost for the usual substation attendant, and no large expenditure for complicated automatic control equipment or heavy copper feeders for long distance d.c. power transmission.

Chief Electrician, J. S. MURRAY.
Follansbee Bros. Co.,
Toronto, Ohio.

Method of Drying Lumber With Electric Heat

BY THE use of electric heat for drying its lumber, the General Electric Co., Schenectady, N. Y., claims that the Chicago Lumber Co. of Oakland, California, has found it can dry its lumber in two days time, without damaging the wood, and with low operating costs.

This company has made two installations of electric lumber drying equipment in its plant. The drying box used has dimensions approximating 10 ft. wide x 7 ft. high x 21 ft. long. The compartment is constructed of ship-lap backed by moisture-proof paper, and insulated with packed shavings. The lumber to be dried is principally short lengths used after drying to make up window and door casings.

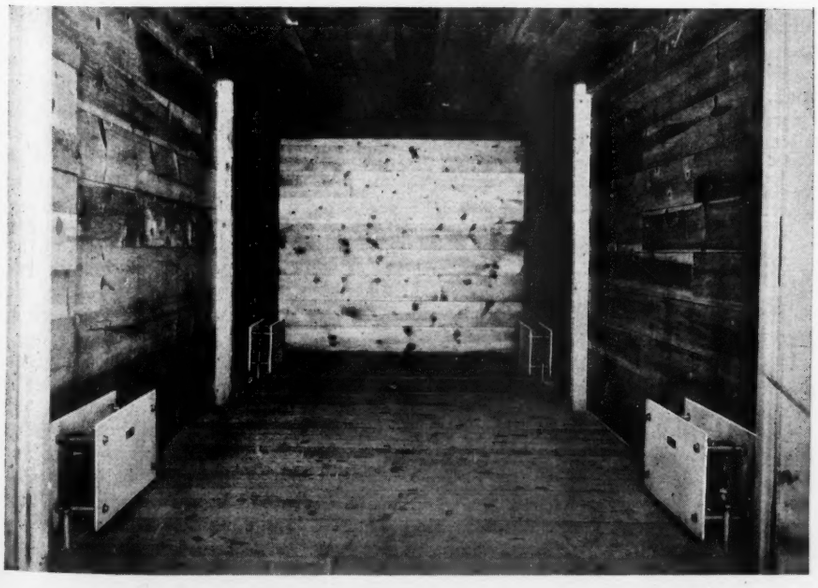
The moisture removed is calculated to be equivalent to 5 per cent of the weight of the dry lumber, and this drying is accomplished within 48 hr. without end-checking or other damage to the lumber. It was estimated before installation that the drying would require 100 kw.-hr. per 1,000 board ft. of lumber, but actual operation has shown a much better economy. The cost of power is 1.15c. per kw.-hr., comparing favorably with the cost of oil at $1.25 per bbl. of 42 gal.

The electrical equipment consists of heating elements with a total connected load of 15 kw., four General Electric form G oven heaters being used. The temperature is automatically controlled at 90 deg. F. at the beginning of the drying cycle and at 120 deg. F. near the end of the period by means of an automatic control panel and a Bristol temperature control.

The cold air is drawn in by natural draft through four openings in the floor of the drying compartment, and a heater is placed over each opening. The hot air rises to the ceiling and there it deposits part of its heat and is cooled off. Then it drops to the floor level before it can pass out through the exhaust air ducts, one on each side of the drying box, which extend from the floor up through the roof. In this manner the air is caused to pass over and through the lumber and pick up moisture on the surface of the lumber. This method is employed so that the efficiency of the oven will be increased.

The temperature controller has a sensitive bulb 25 ft. long which is spread out over the ceiling of the compartment and thus controls the average temperature over the whole of the drying box. The lumber is run into the drying compartment on trucks and is so loaded as to give ample space around each piece to allow free air circulation.

This company has also installed electric heating units in its glue room where window and door sash parts are glued together. In this room, which is 20 ft. x 60 ft. x 12 ft., it is necessary to keep the air heated so that the glue may be thoroughly dried by the time the sash has passed from one end of the gluing machine to the other.



This shows the respective positions of the heating elements and vent ducts.

Disintegration of Studs Due to Defective Slate Panel

TROUBLE with one of our switchboard panels, which was located in a rather damp place, proved to be very elusive until it was discovered that two studs had broken off in the panel. These studs were fastened directly to the panel without any insulation.

After dismantling the connections on the board, it was found that the studs on one side of the d.c. line were surrounded by a white deposit and were being slowly eaten away, while the studs on the other side of the line had dark patches on them.

After a thorough investigation, it was found that the slate panel contained traces of some chemical impurity, and these impurities in conjunction with the moisture formed a high-resistance path between the positive and negative studs.

To remedy this trouble, all studs and connections carrying current and passing through the panel were insulated with mica tubes. Only thin sheets of mica were used, as it was only necessary to prevent the copper and brass connections from touching the slate.

W. E. WARNER.
Shefford, Bedfordshire, England.

Simple Mistakes That Resulted in Failure

I HAVE seen so many mistakes made that it seems hardly possible to mention an original one, although several interesting examples were seen during a recent trip. One mistake occurred in a woodworking plant, where so much care is exercised in fire prevention. Sparks were seen coming out of the cabinet of a potential starter. Upon investigation, it was found that the oil level was low, but instead of using switch oil, ordinary light lubricating oil had been substituted, which was not suitable.

Another job that gained my particular respect was in a large oil refinery that faced a serious predicament owing to the expected failure of one of the main pumps which composed just half of the pumping system. The motor driving this pump developed a heavy knock, causing it to vibrate. Two and one-half days had been spent on this equipment trying to remedy the trouble, for it was essential to keep the unit in service. When I arrived, the motor was still in service, but vibrating as badly as any 200-hp. d.c. motor could and still remain on the foundations. The trouble was readily apparent when I placed my hand on the field coils, finding all except one extremely warm.

The trouble was diagnosed as a shorted field coil, which was evidently correct, for it ran properly afterward.

E.J.M.

MECHANICAL MAINTENANCE OF *Power Drives*

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through the auxiliary transmitting equipment to all driven machines.

Anti-Friction and Sleeve-Type Bearings on Motors

AT THE recent convention of the Association of Iron and Steel Electrical Engineers in Pittsburgh, Pa., Mr. F. W. Cramer, Ass't. Electrical Supt., Bethlehem Steel Co., Johnstown, Pa., presented a paper "An Analysis of the Motor Bearing Problem," which was abstracted on pages 323 and 324 of the July issue of INDUSTRIAL ENGINEER. Some of the discussion on Mr. Cramer's paper was also printed on page 329 of the July issue. The interest with which this paper has been received indicates that Mr. Cramer has made a very valuable contribution to industry on the motor bearing problem. It is very helpful in that it shows the advantages and the disadvantages of both the anti-friction and the old, reliable, sleeve-type bearings. It is only by frank discussions, such as this paper brings out, that we can form opinions on the merits of the two classes of bearings for electric motors.

My experience with motor bearings would lead me to concur in the statements made by Mr. Cramer. The real reason for suggesting the use of anti-friction bearings on mill motors was, in my opinion, the fact that records show that a very large percentage of motor failures is caused by oil leaking out of the bearings and onto the motor winding. This oil, together with the dirt present in steel mills, especially, has caused excessive winding failures. This condition, however, was no fault of the sleeve bearing proper, but was due to the inadequate design of the bearing housing which permitted the lubricant to escape and the gritty dirt to get in. thus shortening the life of the bearing.

It is my opinion that it makes very little difference whether a bearing is babbitted, or consists of steel rollers or balls. If the housing is properly designed, with particular reference to holding the lubricant in and the dirt out, an exceptionally good bearing will result.

We have experimented with both types of bearings during the past five years. We were probably one of the first in the field to try out the so-called sealed sleeve bearings on general-purpose motors at the Toronto plant, in September, 1923. This original set of bearings is still in service. In fact, it ran two years with the original oil. The bearings were taken apart at the end of that time for inspection and found to be in perfect condition. Needless to say, the motor windings were bone dry and the bearings perfectly clean.

We have made about 100 installations of this class of bearings since that time, and at a very small percentage of the original motor cost. The results in every case have been entirely satisfactory. Had we equipped these motors with anti-friction bearings, it would have meant new motor shafts, and scrapping our stock of spare bearings. As it was, we were able to use the latter by making a slight change in the dowel pin holes.

Our experience with anti-friction bearings has been with installations on motors, where no efforts were made by the manufacturers to improve the original sleeve bearing, thus justifying the expense of machining the housings and installing anti-friction bearings. Some of these installations have been successful, whereas others were absolute failures. In fact, I know of one installation where sealed sleeve bearings replaced roller bearings entirely.

In conclusion, so far as I know there are no outstanding examples of where the anti-friction bearings are superior to sleeve bearings, when both are comparable in workmanship and materials; certainly the sleeve bearings are cheaper to install and maintain. However, I hold no brief for the old-style sleeve bearing. I believe that when contemplating the purchase of new motors the advantages offered by both ball bearings and *modern* sleeve bearings should be carefully considered and a choice made that is based on the suitability of the type chosen for the particular application.

J. S. MURRAY.
Chief Electrician,
Follansbee Bros. Co.,
Toronto, Ohio.

Comments on "Application of Gears and Speed Reducers on Motor Drives"

THE article entitled "Application of Gears and Speed Reducers on Motor Drives," by Gordon Fox, which appeared in the April issue of INDUSTRIAL ENGINEER, contains several statements concerning non-metallic pinions which I feel are open to criticism and correction.

In the paragraph beginning at the center of page 163, Mr. Fox refers to the various types of pinion material and then states: "The two latter types (rawhide or cloth) have end plates of brass." In so far as rawhide is concerned, it is true that end plates are used, although other materials are more frequently used than brass. In the case of the "cloth" gear, the use of side plates is the exception rather than the rule. Side plates are used on this type of material only when heavy loads are being driven and added support for the key slot is thought to be essential. In such cases the side plates extend only to a point slightly below the root of the tooth.

It might be well to state before proceeding further that the word "cloth" in this article covers two distinct types of non-metallic gear materials. One type of gear, known commercially as Fabroil, does use shrouds and these shrouds extend to the top of the teeth. The other type of "cloth" gear is a molded product composed of layers of cloth bonded or molded together by a resin compound, such as Bakelite. There are several makes of this type of "cloth" material on the market, sold under such trade names as Micarta, Textolite, Contex, Celleron, Formica, Fabroc, and others. It is of this latter molded type of gear that I write.

In the statement that "brass pinions are particularly adapted to extreme conditions of heat and moisture, which prohibit the use of a non-metallic pinion," we feel that Mr. Fox has overlooked one of the important features of the molded type of pinion, for we have found it to be an excellent article for just such uses. [Manufacturers of such gears state that the molded material is not affected by moisture, cold or temperatures up to about 200 to 250 deg. F.—EDITORS.] Molded gears are also used in applications where a weak acid solution is present, and in plating and similar types of baths which would have a decidedly disastrous effect on any type of metal pinion.

The statement that "the American Gear Manufacturers' Association recently adopted the recommendation that all non-metallic gears or pinions be estimated on a basis of 75 per cent of the rating of cast-iron gears of corresponding dimensions" is correct only from a purely mathematical viewpoint, inasmuch as the 6,000-lb. fiber-stress value at static load adopted for non-metallic materials is 75 per cent of the established 8,000-lb. for the same factor in cast iron.

As a matter of fact, I believe that is where the comparison ends, for we have found that the non-metallic pinion will outwear the cast-iron pinion in the vast

majority of cases and with speeds over 1,500 f.p.m. the inferiority of the cast-iron material becomes more conspicuous as the speeds increase.

On the question of speeds, the author, in the last paragraph on page 163, states in regard to rawhide, "a speed of about 2,000 f.p.m. is a fair average limit, but 2,500 to 3,000 f.p.m. may be used under favorable circumstances," and adds, in regard to cloth pinions, "the allowable surface speeds correspond to the values for rawhide."

Here, again, the author does not appear to recognize the fact that another of the features of the Micarta or molded type of cloth gear is its ability to give excellent service at speeds that would be prohobitive in many metals. Instead of 3,000 f.p.m. being the limit for satisfactory use we can cite instances where Micarta is being successfully used at three times that velocity.

Table I of his article mentions two grades of non-metallic material. The A.G.M.A. has established the factors 6,000 for non-metallic materials and 8,000 for cast iron without reference to grades. Furthermore, the A.G.M.A. at its recent meeting recommended as standard practice the use of a new formula as a substitute for the Barth formula in the stress factor of the Lewis formula for the calculation of tooth loads in non-metallic materials. This formula is $[150 \div (600 + V)] + 0.25$ and is replacing the age-worn $600 \div (600 + V)$.

By the use of the new formula the real value of the resiliency of Micarta and similar molded non-metallic materials is more correctly established in the tooth strengths, and this point, although generally recognized as being present, was never used in computations due to the lack of any specific data upon which the factor could be actually established.

Tests which have been conducted by Prof. Earle Buckingham at the Massachusetts Institute of Technology for about two years on the new Lewis testing machine have determined sufficient data at the present time to permit the establishment of the new formula. Although it is admitted that the new formula may be subject to a slight change after further tests have been made, it is also admitted to be far more accurate in its present condition in the proper determination of the tooth strength properties of non-metallic material than was obtained by use of the old formula of $600 \div (600 + V)$, which was established many years ago on cast-tooth, cast-iron gears running at a maximum pitch line velocity of 1,000 f.p.m.

Merely as a demonstration of the effect of the new formula on gear-tooth strength of non-metallic material, the following tooth loads were obtained by using $[125 \div (150 + V)] + 0.25$ with 6,000 lb. fiber stress for non-metallic material and $600 \div (600 + V)$ with 8,000 lb. fiber stress for cast-iron on an arbitrarily selected pinion of 3-in. diametric pitch, 15 teeth, and 2-in. face width running at the various speeds listed in the accompanying table.

It will be noted from this table that the non-metallic pinion will show approximately the same tooth strength at slightly over 2,000 r.p.m. (or at approximately 1,600 f.p.m. pitch line velocity) as the cast-iron pinion, and for all speeds above that the gain in strength over the cast-iron pinion is quite pronounced.

Speed R.P.M.	Tooth Strength in Horsepower Cast Iron	Non-Metallic
500	9.02	5.63
1,000	12.93	8.93
1,500	15.11	12.06
2,000	16.50	15.00
3,000	18.18	20.72
4,000	19.14	26.42

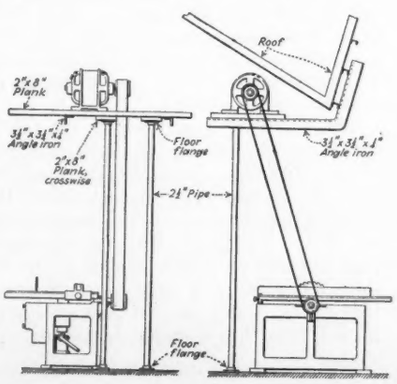
As the tests at the Massachusetts Institute of Technology continue, it will be determined just what additional factor can be placed in the formula to include the wearing properties of the material and when this factor has been determined it is believed that the superiority of non-metallic materials over many of the metals will be quite pronounced. Under certain conditions, the wear on the non-metallic material will be even less than that on hardened steel pinions, we believe.

Although it is appreciated that the article by Mr. Fox was primarily on the subject of speed reducers, and was very ably handled from that viewpoint, I thought it advisable, however, to call attention to certain present-day conditions existing in the non-metallic gearing field with particular attention to the developments that have been announced by the A.G.M.A. in May just after this article appeared. I hope that these comments are taken in the light of constructive criticisms, which is their sole object.

T. C. ROANTREE.
Non-Metallic Gear Application Engineer,
M. & P. Engineering Dept.,
Westinghouse Electric & Mfg. Co.,
East Pittsburgh, Pa.

Supporting Motor Overhead in Saw-Tooth Construction

EVERY industrial operating man has been confronted with the problem of mounting motors, countershafts, or other equipment overhead where there was practically nothing to which they might be attached. Such was the problem confronted in a medium-sized mid-western factory and the solution may be of interest to others, who are called upon to meet similar difficulties.



Method used to mount motor in saw-tooth roof.

The motor is mounted on a platform built of planks attached to heavy angle irons which are bolted to the roof. This platform is held up by upright pipes which in turn are held in place by floor flanges screwed to the platform and the floor.

This plant was of saw-tooth roof construction, of light design, and not intended for supporting loads from the ceiling. When the plant was built, it was expected that the few machines necessary would have individual motors, either built-in or mounted directly on the machine. The product handled was large in bulk but light in weight, so that it was not necessary to use overhead hoists or conveyors. The arrangement of each machine was carefully planned to give ample aisles and storage space for handling the product to and from the machines during the process.

The layout adopted, however, brought two of the woodworking machines under a sloping section of the ceiling, with nothing directly overhead on which to mount the motor. These two machines had been brought from the old plant and were of a type which could not easily be adapted to support the motor. Because of shavings and dust, it was not desired to place the motors on the floor, and a special mounting or platform built up from the floor would not only occupy needed floor space but would be in the way.

It was finally decided to make a special overhead platform for each motor, which was attached to the ceiling but supported from the floor. Accordingly, two pieces of $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$-in. angle irons about 6 ft. long were bent, as shown in the accompanying diagram, to conform to the slope of the roof and bolted to the steel structure in such a manner as to leave the two other ends extend out over the machine. Two 2 x 8-in. planks, about 3 ft. long, were bolted to these outer ends of the angle iron to form a platform for the motor.

Each platform was supported by two pieces of $2\frac{1}{2}$-in. pipe attached to the floor. These pipes were threaded at each end and screwed into floor flanges, which were fastened by woodscrews to the floor and to short pieces of 2 x 8-in. planks mounted crosswise underneath the platform. One of these crosspieces and the pipe was placed directly under the motor and as near to the pulley end as possible, where it would support the most load.

This mounting, which placed the motor about 3 ft. away from the valley in the saw-tooth roof, was very substantial and practically free from vibration. The pipe supported the entire weight of the motor and platform, which in turn was tied to the ceiling from the side by the angle irons to prevent side motion. The planks in the platform were notched to let the belt pass through. The same method of construction could be used to support a countershaft, provided the side pull of the driving belt was not too great.

E. G. H.
Chicago, Ill.

In the Repair Shop

This section is devoted to repair work on electrical and mechanical equipment. Special attention is given to shop or bench tools and short cuts or improved methods of handling work of this character. Contributions are always welcome.

Specifications for Testing Insulating Varnishes

THE method of testing insulation varnish, which is described in this article, I have found very satisfactory, especially for manufacturers of electrical equipment whose laboratory apparatus is limited. As these tests should be comparative, the various brands of varnish on hand should be tested at the same time in the same oven, so as to be absolutely fair to the different brands, for the test temperature is largely the deciding factor.

It will be well to remember that the following specifications for testing insulation varnish are not only useful to check the grade of varnish ordinarily used, but to determine the quality of new brands of varnish.

(1) *Materials Covered*—These tests are intended for varnishes which are applied by brushing, dipping or spraying and are primarily for the purpose of providing electrical insulation.

(2) *The Working Viscosity*—To find the working viscosity, cut pieces of good bond paper about 4 in. x 20 in. x 0.0024 in., drawing an ink line across the paper every 2 in. starting from the top. Then immerse these prepared sheets to the top line in clean varnish free from air bubbles and at the specific gravity recommended by the manufacturer. Then withdraw evenly and rapidly, and allow it to drain thoroughly in a vertical position. Bake or air-dry the sample long enough to set the varnish, and then immerse again as previously directed. Then bake 12 hr. at 200 deg. F. Measure the thickness in mils at each of the inked lines or every 2 in. in case of black varnish. From this thickness subtract the thickness of the paper and divide by two. This result will give the working viscosity or slip of the varnish.

(3) *Time of Drying*—Specimens for this test shall be pieces of 0.0025-in. bond paper similar to that used in making working viscosity tests. The specimen should be dipped once in the varnish, withdrawn rapidly and allowed to drain in vertical position, and either air-dried or baked according to material to be tested. The baking temperature should be 200 deg. F. and the air-drying temperature 70-deg. F.

Examine the specimen every 30 min. to find the setting time or that at which, when pressed with your finger, a mark will be made which is not obliterated by further flow. (Baking varnish to be at baking temperature.)

The surface drying time is when the sample may be pressed tightly between thumb and finger on the 12-in. line and does not adhere.

The hard drying time is when a sheet may be doubled and the 2-in. and 12-in. marks pressed together without sticking.

The cracking time is when the sample can be doubled and drawn taut over a $\frac{1}{8}$-in. mandrel.

This is very important, as the varnish that remains flexible the longest will, in most cases, be the best for armature winding, as it will stand up the longest under the heating and drying action of armature running under load.

(4) *Dielectric Strength Test*—Specimens for the dielectric strength test shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 22 in. x 22 in. and about 0.05 in. thick, into the varnish. This varnish should be tested at the specific gravity recommended by its manufacturer.

Each specimen shall be dipped twice as specified in drying test, but allowing each coat to drain in the opposite direction in order to give a more uniform thickness of coating. The specimen should be dried after each dip in the opposite vertical position from which it was dipped. The time of drying shall be as indicated in the hard dry test.

The dielectric strength of the two films of varnish shall be determined by applying alternating potential to two brass disks, 1 sq.in. in area and with edges rounded to a radius of 0.25 in., which are placed opposite each other in contact with the two sides of the specimens and directly under a pressure of 1 lb. The potential should be applied at a low value and gradually raised at a rate of approximately 500 volts per sec., until puncture occurs. Ten such punctures are to be made at points every 2 in. along each specimen. In each test, the thickness of the films of varnish is to be determined as near to the point of puncture as practical.

The volts at puncture, the net thickness of insulation, and the volts per mil of net thickness, should be reported for each of the ten tests, together with the average maximum and minimum volts per mil. NOTE: It is very important that the circuit is not broken from the time the voltage is applied until puncture takes place. If the contact should be broken, the voltage should be run down to not more than 200 volts, and then start the puncture test all over again. For this reason a transformer with taps on it should not be used, but use an induction regulator in series with the primary of the testing transformer that should have a capacity of at least 5 kw. for voltages up to 2,500, 10 kw. from 2,500 to 5,000, and so on.

(5) *Water-Acid Test*—The specimens used for the water absorption test shall be brass rods 0.5 in. in diameter, 6 in. long, and carefully rounded at one end to a ball shape and polished smooth. These specimens, after thorough cleaning, shall be given three coats of varnish dipping so as to leave bare 1 in. of the rod at the end opposite the rounded end. Each coat should be allowed to drain for 1 hr. at room temperature, and then baked for $\frac{1}{2}$ hr. at 200 deg. F.

After last coat has been applied, the test pieces should be baked at least 10 hr., at 200 deg. F., and at least three specimens for each brand of varnish used should be made. They should be immersed for 4 in., not being allowed to touch the vessel containing the solution, in a solution of 1 gal. of distilled water to which has been added 1 oz. of pure sulphuric acid (H_2SO_4) at a temperature of 70 deg. F. The voltage drop between the solution and the brass rods should be measured immediately upon immersion and every 24 hr. after until failure, using 220-volt, direct current. Should specimens break down when first tested, they should be made. If three different specimens break down, the sample shall be considered as unsatisfactory. During the test the temperature of the solution should be kept at 70 deg. F. NOTE: A simple method of making the connections is to connect a voltmeter between each rod in turn and one side of a 220-volt direct-current circuit, the other side of the circuit being connected to the solution through any suitable piece of metal suspended in it. The resistance will be inversely proportional to the deflection of the voltmeter pointer; that is, the smaller the deflection the greater the resistance. Failure of the material will, therefore, be indicated by a sudden increase in the deflection of the voltmeter pointer.

The resistance between each rod and the solution should be measured once a day, and the number of days elapsing until breakdown occurs shall be taken as the resistance of the varnish to that particular medium.

(6) *Oil Resistance*—To test the effect of oil, use pieces cut from the dielectric strength test specimen, after they have been punctured and measured.

Immerse them half way in transformer or machine oil, at a temperature of 200 deg. F., and note time of softening until film may be removed by pressure and drawing through thumb and finger. Also, upon another piece the time required to cause blistering; this last piece should never be handled. The average of these two in hours shall be considered the oil resistance.

(7) *Aging Test*—Strips of muslin, which have been treated with the varnish in a way similar to the preparation of the paper strip in the drying test, shall be prepared and hung in the shop. A record should be taken every month to note any deterioration due to aging of the varnish.

(8) *Penetration Test*—Muslin shall be folded over until it forms about 40 layers. A $\frac{1}{16}$-in. water gage glass containing about 6 in. of the varnish to be tested will be placed with one of its ends on the folder muslin and allowed to stand in vertical position for 30 sec. The depth of penetration of the varnish into the cambric will then be reported as the number of layers that the varnish has penetrated.

V. A. PARTZ.
Consulting Engineer
American School,
Chicago, Ill.

Method of Drying Out Shunt Field Coils

A SHORT time ago several 250-volt, d.c., shunt-wound motors, ranging in size from 10 to 25 hp., were flooded. This occurrence, of course, necessitated the drying out of the motors and so the following method was employed:

A current was applied to the shunt coils at a lower voltage than that under which they would normally operate. As moisture will cause short circuits between the turns themselves at the normal motor voltage, it was thought advisable to start the drying out current at a low voltage, which could not burn the insulation even if there was practically a dead short between the turns. So 25 volts was considered a safe pressure at which to start the drying process. As the voltage was gradually increased, the temperature of the coils was watched so that their maximum temperature limit would not be exceeded.

This temperature was carefully determined by holding the bulb of a thermometer, under a piece of waste, tightly against one of the coils. To remove all the moisture in the coils in a reasonable length of time (in all probability less than 48 hr. will always suffice) a 75-deg. C. rise above the surrounding air was considered as high as it would be necessary to go.

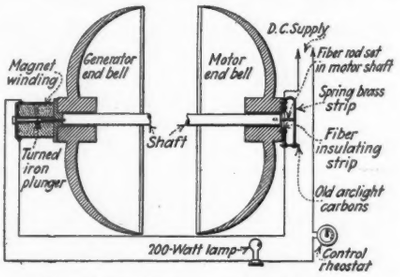
Alternating current, when obtainable, is more effective than direct current, for the eddy currents set up in the pole pieces cause heating of the iron and bring the heat more directly in contact with the inside turns. In this case where so many motors are involved, it was most convenient to have one generator set aside for the purpose of supplying the drying out current, and the voltage regulated by varying the field current of this generator. Another plan that could have been employed, if a generator had not been available, would be to drive a 50-hp., shunt-wound motor as a generator.

As the resistance of shunt field coils is quite high, they draw very little power; so the generator was used to dry out several motors at the same time. During the drying out process the motors were covered with tarpaulin.

ARTHUR F. HANLY.
New York, N. Y.

Preventing the Wearing of Grooves in Commutator

IN A plant, which I recently had occasion to visit, I noticed a very interesting method of preventing the brushes on the d.c. generator of a motor-generator set from wearing grooves in the commutator. This was accomplished by causing the armature and shaft to move slowly first toward one end of the generator and then toward the other. In this case it can be seen that the brushes are not allowed to make contact continuously in one place. Consequently the forming of grooves by the brushes is prevented.



This shows how a solenoid is employed to oscillate an armature shaft.

This sliding movement of the armature first toward one end of the set and then toward the other is caused by the shimming up of one end of the motor-generator set, which causes the armature to slowly slide by gravity toward one bearing, and when the armature has approached its limit of travel in this direction a contact is made which causes a magnet to be energized, and this magnet slowly forces the armature toward the high end of the set. When the armature approaches the higher end of the set, the magnet is de-energized and the armature again slowly slides by gravity toward the lower end of the set.

An electromagnet of the solenoid type was secured to the commutator end bell of the d.c. machine and inclosed in a suitable metal case to protect the windings from mechanical injury. On the outboard end bell of the induction motor there was a make-and-break device, actuated as shown in the accompanying diagram, that controls the current to the magnet by turning it on and off at the proper times.

The size of the magnet and corresponding parts will, of course, vary according to the size and weight of the parts to be oscillated, and it will be necessary to either shim the end bells to allow for the desired shift or turn down the oil flanges of the shaft.

This device for slowly oscillating the commutator has proven entirely satisfactory in this particular plant and I believe it will help to overcome some of the minor commutator troubles encountered in others.

PHIL D. COMER.
San Bernardino, Calif.

How to Determine Reason for Reduced Speed of a Squirrel-Cage Motor

FREQUENTLY I am called upon to determine the reason for the slowing down of an ordinary induction motor. At such times the procedure that I generally employ is as follows:

First, ascertain if the voltage and frequency of the circuit are correct. In case the voltage is too low a decrease in the torque and consequently the speed of the motor will result. If the frequency is below the proper value, it would, of course, cause a corresponding decrease in speed. When both the voltage and speed are correct at no load, the motor itself should be examined next.

Look over the windings for short or open circuits. A short circuit will usually indicate its existence by causing the motor to take excessive current; also by overheating the insulation. In three-phase motors one of the phases might be inoperative, due to open circuits. In the rotor, especially in motors of the squirrel-cage type, there may be open circuits cutting out part of the winding, thereby reducing the torque. Also any loose connections in the rotor will increase the effective resistance of the rotor, and thus cause increased slip.

I have seen some cases where the solder used in connecting the end rings to the squirrel-cage rotor bars had been melted, and thus caused the rotor resistance to rise. The motor in such cases is rendered unfit for service until the rotor is repaired.

Should the windings prove to be satisfactory, next ascertain what load the rotor is carrying, for overloads will, of course, cause the motor to slow down. If the cause of the trouble still remains unrevealed, it will doubtless prove to be of a mechanical nature.

So the bearings should then be inspected to see if they are too tight, or the shaft is sprung or bent, thus causing excessive bearing friction. Should these points fail to disclose the trouble, the air gap of the motor should be checked. If the depth of the air gap is too great, there will be an abnormal leakage of flux and a corresponding reduction of speed and torque. An unequal air gap may be caused by worn bearings or by an incorrectly lined up armature. In either case there will be too large a gap on one side of the rotor, and too small a one on the opposite side. At times the rotor may be found enough off center to rub against the field punchings.

H. J. ACHEE.
Superintendent
City Water & Light Dept.,
Woodward, Okla.

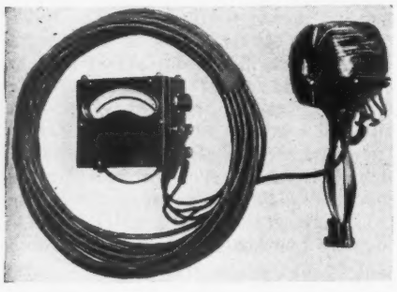
New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Current Measuring Set

A SPLIT-CORE current measuring set for determining the load on feeders or distribution networks has been developed by the General Electric Co., Schenectady, N. Y. This set, which can be used for measuring the current flowing in a conductor without opening the conductor to insert an ammeter or a current transformer, consists of a



General Electric Pliers-Type Current Measuring Set.

transformer with a hinged magnetic circuit, leads, and one or more ammeters.

When taking a reading the transformer, which operates like a pair of pliers, is clamped around the conductor, with one hand. Flexible multi-conductor leads 50 ft. in length are supplied with each set.

Two sizes of transformers are supplied, one having a window opening of 1¼ in. and the other 2¼ in. in diameter. The former is rated 75/125/250-amp. primary, 2.5-amp. secondary, when used with a single indicating ammeter. A small indicating ammeter, Type P-8Y, is furnished. It has a cylindrical switch by means of which the various ratings of the set can be readily obtained without changing connections at either the transformer or the ammeter.

The recording instrument listed as standard with the sets is Type CRP-4, a portable, round-pattern instrument with an 8-in. diameter chart and one-day clock.

Forged-Cast Spur Gear

PRODUCTION on the Forged-Cast spur gear has been announced by The Hill Clutch Machine & Foundry Co., N. E. Corner Breakwater Ave. and W. Sixty-fifth St., Cleveland, Ohio. These gears, according to the manufacturer, consist of a forged-steel rim, in which the teeth are cut, with semi-steel cast hub and arms. After casting, the completed gear is finish machined and the teeth cut. It is stated that the junction of the steel rim and the semi-steel center is a laminated weld of steel and iron and the finished gear is one integral piece. The thickness of the forged rim is proportioned to the teeth. This process of combining a forged-steel rim and cast arm and hubs is also used for the production of flywheels.

Link Belt Conveyor Idler

ANNOUNCEMENT has been made by the Link-Belt Co., Chicago, Ill., of the introduction of its anti-friction belt conveyor idler and return rolls.

One of the outstanding features of the idler is the protection afforded by a labyrinth grease seal, mounted in a grease cap which also serves as an outboard reservoir and lubricates the bearing on the outside as well as on the inside, especially when the roll is on an incline. This, in turn, is protected by a deflector plate which keeps dirt, dust, grit or any foreign material away from the bearings and grease seal.

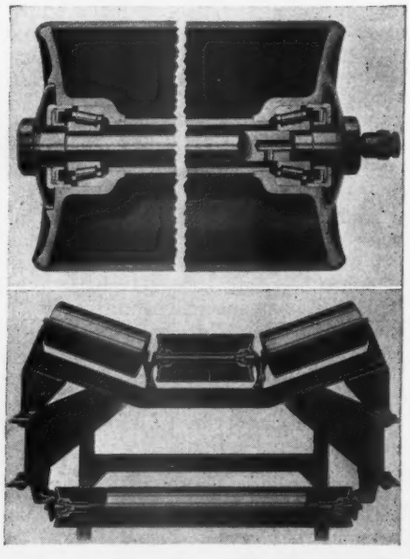
The rolls are mounted on a self-cleaning "T" base and are interchangeable. The entire frame is riveted. The bearings are of the Timken tapered-roller type, which are totally encased within the roll hub.

It is claimed also that the design and construction of the roll make it practicable to vary the characteristics of the material used for the roll shell. Further, a special iron has been developed for use in coke plants, for resisting the corrosive action of sulphuric acid fumes and the abrasiveness of coke dust.

The idler rolls are supported in malleable-iron brackets having a large bearing surface and are not dependent upon the use of slots. The brackets are so constructed as to support the ends of two adjacent rolls, and the roll shafts are supported at both ends close to the rolls, without overhang.

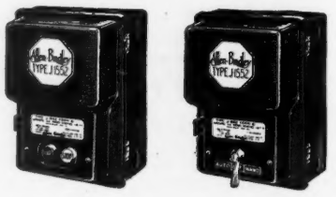
Rolls are spaced far enough apart to permit convenient removal from the frame by simply lifting them out. The end stands, which are riveted to the "T" iron base, are spread at the foot to present a rigid support for the idler.

Link-Belt Anti-Friction Belt Conveyor Idler.



Across-the-Line Motor Switch

ANNOUNCEMENT has been made by the Allen-Bradley Co., 286 Greenfield Ave., Milwaukee, Wis., that it has recently added the Type J-1552,



Allen-Bradley Type J-1552 Form B Switch.

Form B switch to its standard line of across-the-line starting switches. The Form B size marks a new development in magnetic motor starting switches, it is stated, because it extends the advantages of push-button control, thermal overload relays, and no-voltage protection to the smaller sizes of motors that heretofore have been started only with knife switches. The new type J-1552, Form B switch is made for motors up to 1½ hp., thus bringing these small motors within the range of push-button operation.

The Form B switch is approximately 8 in. high, 6 in. wide and 4½ in. deep. The Form B-1 switch, shown closed, is equipped with start-and-stop push buttons in the switch cover. The Form B-2 switch is similar to the Form B-1 except that it is without push buttons. The Form B-3 switch, also shown, has a two-way lever switch for automatic and hand control.

Across-the-Line Starter for 5-Hp., A. C. Motors

DEVELOPMENT of the new C-H 9586 AAA starter shown in the accompanying illustration is announced by The Cutler-Hammer Manufacturing Co., 1,219 St. Paul Ave., Milwaukee, Wis. This new Cutler-Hammer product has been designed to handle motors of 5 hp. rating and under, gives push-

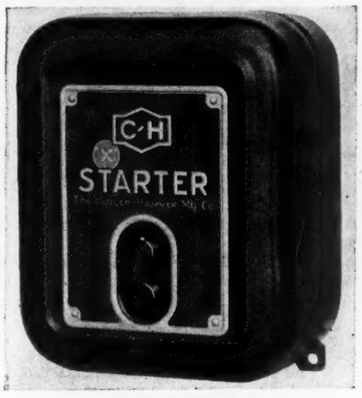
button control of starting and stopping, provides thermal overload and no-voltage protection and is no larger than a telephone box.

The small size permits mounting of the starter, in most cases, where the control station would ordinarily be placed. However, one or more push-button stations may be used if desired.

A novel feature is the type of contactor developed for use in this starter. A roller is forced between two fingers to complete the circuit; thus a double break and a wiping contact are secured. These fingers may be removed and new ones inserted without the use of tools. Ease of disassembly is one of the advantages claimed for the starter.

To adapt the starter for any horsepower within its rating it is only necessary, it is stated, to insert the proper-sized heater coils in the thermal overload relay.

The overload relay is reset by pushing the stop button. The motor can then be started by pushing the other button, providing the overload has been removed so that the relay does not again trip.



Cutler-Hammer 9586 AAA Across-the-Line Starter.

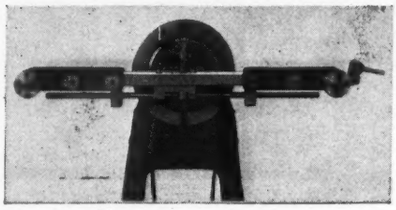
Loop Winder

THE Super Speed loop winder has been announced by the Armature Coil Equipment Co., 2,514 Forestdale Ave., Cleveland, Ohio.

A single lever movement draws in one slide block on a cam motion, allowing the loop to be removed from the pins. A spring tension returns the lever to the proper winding position and therefore prevents any possible chance of winding a short loop.

There are no catches or triggers, and the slide block or carriage, which is 9 in. long, gives a long bearing on the 1 in. x 2 in. flat bar on edge, thus preventing any chance of the bar springing. The extra length of carriage allows a 36-in. loop to be wound by using only a 30-in. winding bar.

The slide block has three positions to insert winding pins, making it possible to wind long or short loops, and the blocks are clamped by a split vise to each rod. One rod is controlled by a cam that allows the loop to be removed;



Super Speed Loop Winder

the other rod, however, is held stationary.

The loops are started and finished in the same position and the two lead holders permit leads to be started on any side of the coil. These holders are of the revolving type and are quick acting. There are two sets of winding pins furnished; a quick snap-on set, and a screw-on set. The total weight of this set is about 15 lb. net.

Crane Trolley

ANNOUNCEMENT has been made by the Shepard Electric Crane & Hoist Co., Montour Falls, N. Y., of a new standard type crane trolley. The design includes a balanced drive, a straight-line construction in units each separately accessible, and an automatic oil bath lubrication.

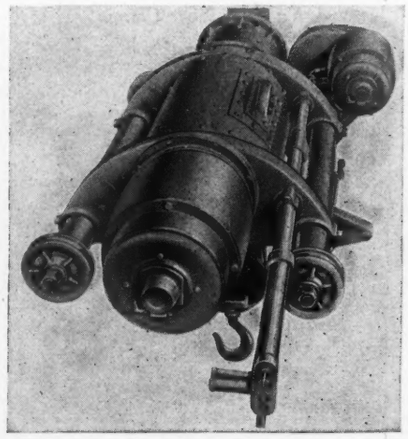
The construction of these crane trolleys in changeable sections permits each trolley to be built up of units particularly suitable for the service intended.

The frame is carried by axle brackets consisting of heavy seamless drawn steel tubes passing through bored openings in the girts, and the entire load-carrying structure from trolley wheels to winding-drum is of steel.

The trolley motor like the hoist motor may be mounted by bolting its field frame to an adapter, or as an alternative, upon its feet on a shelf near the center of the driven axle bracket. Any type of motor, solid or split frame of appropriate size, may be used.

The trolley axle bearings are waste packed and supplied with oil cellars communicating with a pool retained within the axle bracket tubes. Oil for

Standard Type Crane Trolley Manufactured by Shepard Electric Crane & Hoist Co.



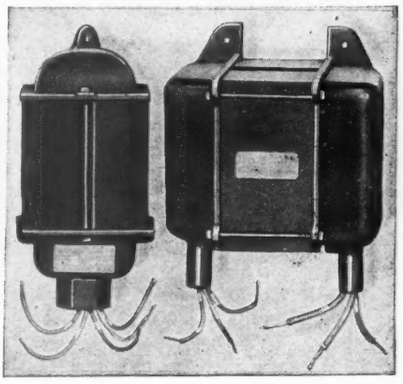
all four bearings is supplied through a single pipe connecting both axle bracket tubes.

The trolley gearing, although similar to former designs, has been made more ample in size, permitting larger gears and gear ratios. The load block is fully inclosed.

Air-Cooled, Dry-Type Transformer

COMPLETION of engineering work and preliminary operation tests on the line of Trester air-cooled, dry-type transformers is announced by the Trester-Service-Electric Co., 55 E. Wells St., Milwaukee, Wis. Two of these units are shown in the accompanying illustration. These transformers are wound on cores built up of silicon steel, it is stated by the manufacturer.

The whole transformer core and windings after being assembled are treated in a high-grade insulating varnish and baked to increase the dielectric strength of the insulation and to prevent absorption of moisture. To protect the windings from mechanical injury, cast-iron shields are fitted and bolted to the cores. It is stated that, once installed, the transformers need no further attention and that the amount of power consumed, when not supplying a load, is negligible. Extra-flexible, rubber-covered leads are brought out and carefully marked to conform with standard practice. All splices are made in the terminal box which is attached to the bottom of the transformer. Conduits can be run directly to the box, thus eliminating all exposed wiring and at the same time grounding the transformer through this connection. The larger sizes of units from 5 to 20 kva. are equipped with standard conduit connections.



Trester Air-Cooled, Dry-Type Transformer.

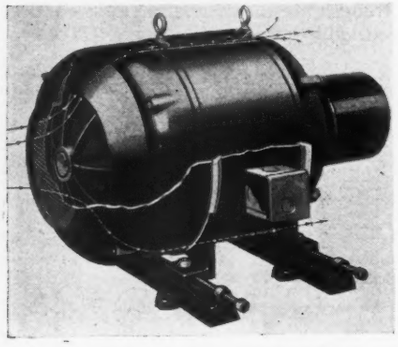
These units are made in ratings from ½ to 20 kva. Units up to 4 kva. are made of the type shown at the left. The larger sizes above 5 kva. are of the type shown at the right. A complete range of ratings listed is ½, 1, 2, 3, 4, 5, 6, 8, 10, 15, and 20 kva.

The type TRN is a two-winding or insulating transformer which is made

for single-, two-, or three-phase, 220- or 440-volt, 60- or 25-cycle primary. The Types TRNC and TRNS are single-winding transformers of the auto transformer type, and are made for single, two, and three phases. This unit is not recommended unless connected to a grounded primary system nor is it recommended for more than 240 volts. Type TRB is a balancing transformer of the single-winding type with a tap in the middle to convert 220 volts power circuit to 110 volts for supplying power for lighting circuits or operating other appliances. This Type TRB transformer is not recommended for lighting circuits where the electric code requires that the neutral must be grounded.

Self-Ventilating Motor

THE Howell Type K totally inclosed, self-ventilating motor has been announced by the Howell Electric Motors Company, Howell, Mich.



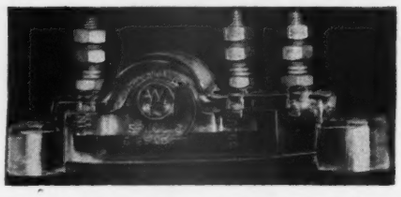
Type K Totally Inclosed, Self-Ventilating Motor.

This totally inclosed motor is of the external cooling type. The unit consists of a standard motor surrounded by a shell, which allows about ½-in. clearance between the shell and the motor. Air is forced at a high velocity through this space by a fan mounted on the motor shaft. In this way piping is eliminated—a motor frame only slightly larger that that employed in the normal motor can be used—cooling air does not enter the motor—foreign matter cannot get in the motor to injure or in any way impair or attack the windings—and, it is claimed, the costs are materially reduced over the ordinary totally inclosed motor. This motor is built with Timken roller bearings only.

Autovalve Arrester

TO GUARD low-voltage systems against insulation breakdowns, including failures of relays, transformers and other apparatus resulting in interruption of service, a low-voltage autovalve lightning arrester has been introduced by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

This arrester may be applied to alternating-current systems that operate at 65 volts or less and also on direct-current systems that operate at 45 volts or less. Some of the circuits to which this arrester may be applied advantageously include all manner of signal circuits, fire alarm systems, remote metering circuits and current transformer primaries.



Westinghouse Low-Voltage Autovalve Arrester.

The arrester is glass encased with clear moisture-proof glass, making every part of the arrester visible without removing the seal in the bottom. It is claimed that low resistance makes it possible for a discharge current of 1,000 amp. to flow through the arrester without causing any dangerous voltage across it. Leakage currents have been reduced to a minimum by the use of the autovalve principle and the moisture-proof glass case.

Hose Clamp

A NEW hose clamp has been introduced to the trade by the National Clamp Co., 16 East 41st St., New York, N. Y. From the illustration it may be noted that it consists of a band upon which is embossed a series of transverse ridges and depressions, forming in effect a toothed rack. The screw engaging with this toothed band is mounted on a trunnion.

In applying the clamp, the band is slipped over any part of the hose and compressed by hand. Allowing the screw to swing into position and taking a few turns with a screwdriver tightens the band. The screw, operating as a worm drive, feeds the band under the screw thread. This method of tightening the band, it is claimed, insures complete contact and equal pressure around the entire periphery of the hose.

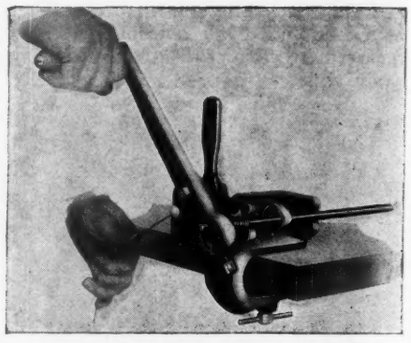
The clamps are made in four sizes: Nos. 10, 20, 30 and 40. Size No. 20, for example, will fit hose from 1 in. up to and including 1¾ in. inside diameter.

National Hose Clamp.

Spring Winder

A SPRING winding machine has been put on the market by the Fostoria Screw Co., Fostoria, Ohio. It is claimed that any apprentice can, with the device shown in the illustration, in a minute's time make a coil spring of any size from ⅛ to 1¼ in., using any gage wire from the finest piano wire to ⅜ in. It is designed to wind a right or left coil of any length and pitch, either of the compression or expansion type.

The size of the spring depends upon the size of the mandrel over which the wire is wound, while a tapered cam determines the lead or pitch. When the tapered cam is withdrawn from contact with the wire an expansion type of spring results. These rapid spring winders are furnished complete with large and small handles and also with a ⅞-in. mandrel and a wrench.



Spring Winder Manufactured by Fostoria Screw Co.

Alternating-Current Contactors

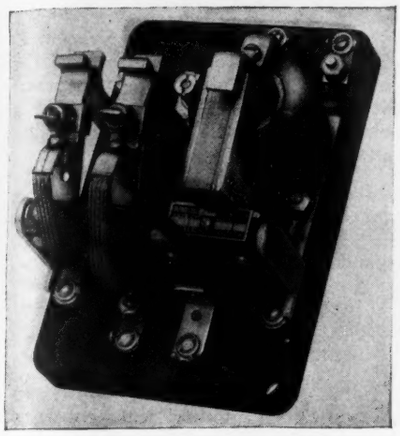
ANNOUNCEMENT has been made by the General Electric Company of Schenectady, N. Y., of a small alternating-current contactor for general application. It is self-contained on a molded base measuring 6½ in. x 4½ in., and two main poles rated at 15 amp. and a normally open interlock are provided.

This device takes from 3 to 6 watts and will, therefore, operate from a 50-watt bell-ringing transformer. Among the important features are the following:

A molded shaft is used. This is relatively new in contactor construction. The shaft bearing itself is of Bakelite and operates in bronze shaft bearings. The contactor bears the G. E. designation CR-2810-1332, and is made in four forms.

Form A is made with a short magnet gap, making it particularly suitable for thermostat control applications. This form is limited to 220 volts on the contact tips. Form B is made with a wider tip gap and is provided with a barrier between the tips. It has been given the following horsepower ratings: for 110 to 220 volts—2 hp., three phase;

for 440 volts—1½ hp., three phase; and for 550 volts—1 hp., three phase. Forms C and D are the same as Forms A and B respectively, except that they are back-connected. In this form the



Small A.C. Contactors Manufactured by the G. E. Co.

unit assembly is retained, but extended screws are used to permit mounting on a base for back-connection.

Paint Spray Unit

A PAINT spray unit, known as the Milburn Type El siphon-feed outfit, has recently been placed on the market by The Alexander Milburn Co., 1416-1428 West Baltimore St., Baltimore, Md.

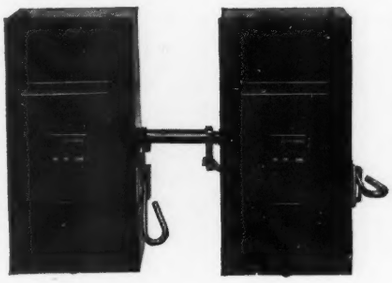
This unit consists of the Milburn Type E gun with a quart container, air purifier, air regulator, and 25 ft. of air hose with the necessary connections. An ordinary garage air compressor affords a sufficent volume of air to operate the gun.

As the air, upon entering the purifier, passes through a series of double baffles and moisture and other impurities are extracted from the air. The Type El outfit with the Type E gun furnished is adaptable to a wide range of painting, and it is claimed will operate efficiently whether using a heavy anti-corrosive paint or a very thin lacquer. The gun can be adjusted for such fine work as touching-up, shading and high-lighting larger work and for coarse work such as walls or ceilings. The atomized spray is surrounded by an air pocket which is designed to lessen the loss of material.

Alexander Milburn Paint Spray Unit.

Dual Service Switches

A NEW type of dual service entrance switch has been announced by the Palmer Electric & Manufacturing Co., of Cambridge, Mass. It is stated that dual service entrance control from duplicate feeders is provided for in capacities ranging from 30 to 400 amp., 250 volts, two, three, and four poles, by a recent addition to the Classification *AA* line of inclosed fuse switches manufactured by this company. The new switch consists of two standard Classification *AA* fuse switches provided with a mechanical interlock that permits either one of the two services to be connected to load. Each service connection is fused and inclosed in a separate switch cabinet.



Dual Service Switches Made by Palmer Electric & Manufacturing Co.

Ohmmeter

A NEW measuring device known as the Ground Ohmer is a Siemens & Halske product, and Herman H. Sticht & Co., 15 Park Row, New York, N. Y., are the exclusive sales agents for the United States. This direct reading portable ohmmeter is a compact unit, which, as illustrated, is entirely self-contained.

A hand-operated 35-cycle generator is used as a source of current for feeding the current transformer, which has two windings in the ratio of 1:1 and 1:10. These ratios enable the bridge to be adjusted over a range of 25 ohms or 250 ohms.

The galvanometer is of the shielded dynamometer type, and a noteworthy feature of the device is the zero adjuster of the moving system of the galvanometer. This adjustment is designed to offset the influence of stray currents. The screw anchor, or other ground devices, are placed 20 and 40 yards away from the resistance to be measured.

S & H Ground-Ohmer.

Outdoor Switchhouses

SEVERAL changes have been made by the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., in the past three months in the design of its new outdoor switchhouses.

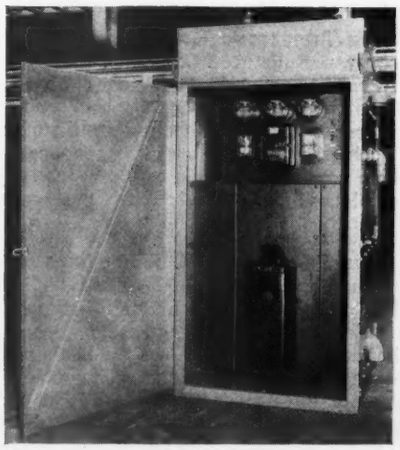
In addition to the most prominent change, the reduction in height, which gives a more compact single unit and also allows ready mounting under existing structures and buses, there is another very desirable feature—the complete isolation of the front from the rear of the houses without decreasing accessibility.

As the meters and relays are now mounted on steel instead of slate panels, additional bracing is provided to the houses by this arrangement and the possibility of any panel breakage is thereby eliminated.

The circuit-breaker control relay is mounted in a glass case to remove all danger of anyone coming in contact with live parts in the front of the switchhouse.

This enables the central stations to utilize the services of a more or less inexperienced man to obtain meter readings.

Westinghouse Outdoor Switchhouse.



Trade Literature
you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

AIR-COOLED TRANSFORMERS—The line of Trester air-cooled, dry-type transformers rated from ½ to 20 kva. are described and illustrated in Bulletin 527. This line includes two-winding or insulating transformers, single-winding or auto transformers and balancing transformers.—Trester-Service Electric Co., 55 E. Wells St., Milwaukee, Wis.

REBUILT EQUIPMENT—The monthly Bargain Sheet lists and prices various units of Hi-Grade-Rebuilt motors, generators, motor-generator sets, transformers, meters, and other electrical equipment.—Gregory Electric Co., Sixteenth, Lincoln and Wood Sts., Chicago, Ill.

COPPERWELD PRODUCTS—A folder gives the various types of Copperweld products and indicates in tabular form the various uses which are made of them.—Copperweld Steel Co., Braddock P. O., Rankin, Pa.

SPEED REDUCER—Book 630 illustrates the construction and gives specifications for the two new types of Caldwell speed reducers, which are especially designed for use in connection with conveyor and elevator service and for screw conveyors.—H. W. Caldwell & Son Co., Western Ave. at Seventeenth and Eighteenth Sts., Chicago, Ill.

DUST COLLECTING—Bulletin 9 (revised) describes the Draco dust collecting installation at the cement plant of the Ford Motor Co.—The Dust Recovering & Conveying Co., Harvard Ave. & E. 116th St., Cleveland, Ohio.

OILLESS BEARINGS—A folder contrasts the application of ordinary bearings on loose pulleys with Arguto oilless bearings on loose pulleys.—Arguto Oilless Bearing Co., Wayne Junction, Philadelphia, Pa.

SELF-THREADING UNIONS AND CONNECTORS—Bulletin 2098 describes and illustrates applications of the Crouse-Hinds self-threading unions and connectors for use in connecting fixed runs of conduit or bent or offset sections which would be difficult to screw into a condulet.—Crouse-Hinds Co., Syracuse, N. Y.

LINE PROTECTION—A recent issue of the monthly publication entitled "The Line" describes a porcelain-inclosed throttle fuse and a 90-deg. gravity stop. The latter, it is said, allows the blade of an indoor, vertical-mounted, double-throw or selector switch to be held in a rigid, open position, thus eliminating the possibility of the open blade falling upon the lower contact. The catch is of such construction, however, that the switch blade can be thrown into the lower contact, if desired.—Line Material Co., South Milwaukee, Wis.

EXCAVATOR AND CRANE—Bulletin BH-1 describes the P & H Groundhog, Model 300, which can be used as a ½-cu.yd. shovel, dragline, clamshell, crane, or pile driver by changing the boom and attachments. This all-around, full-revolving unit is mounted on corduroy treads.—Harnischfeger Corp., Milwaukee, Wis.

ELECTRIC TOOLS—A loose-leaf catalog illustrates and gives specifications for the various Standard electric drills, grinders and other tools manufactured by this company.—The Standard Electric Tool Co., Cincinnati, Ohio.

CABLE END BELLS—Bulletin 20 gives specifications and dimensions of the line of indoor cable end bells.—Electrical Engineers Equipment Co., Melrose Park, Ill.

TRAMRAIL—A 64-page catalog describes the Atlas Duo-Rail track and carriers and illustrates a large number of installations. This is a double-rail tramrail system.—The Atlas-Chicago Co., Division of Chicago Electric Co., 740-744 W. Van Buren St., Chicago, Ill.

INDUSTRIAL LIGHTING—Numerous installations of X-ray reflectors in industrial plants and considerable lighting data are given in serial 448.—Curtis Lighting, Inc., 1119 W. Jackson Blvd., Chicago, Ill.

ELEVATORS—Book 680 devotes 44 pages to a discussion of modern types of elevators for handling various loose materials and gives a discussion on how to select an elevator. A table indicates the type of elevator to use for handling various materials.—Link-Belt Co., 910 So. Michigan Ave., Chicago, Ill.

VARIABLE-SPEED CONTROL—Bulletin describes the push-button electric remote control which is built into the Reeves variable-speed transmission unit.—Reeves Pulley Co., Columbus, Ind.

BATTERY TRICKLE CHARGERS—Booklet TC-8 describes the trickle method of charging storage batteries and illustrates the Balkite line of trickle chargers, now available for industrial service. The two new compact unit types RA and RB for alarm, signal, telephone, and switch-operating batteries are fully described. This booklet will be especially helpful to those not familiar with the trickle charging principles.—Fansteel Products Co., North Chicago, Ill.

FLEXIBLE COUPLING—The Sykes universal shaft coupling, which is used for compensating for misalignment between connected shafts, is illustrated in a folder.—Farrel Foundry & Machine Co., Buffalo, N. Y.

INDUSTRIAL MESH—A group of circulars illustrate a few of the numerous uses of Steelcrete industrial mesh, an expanded metal, for guards, screens, inclosures, and numerous other industrial uses.—The Consolidated Expanded Metal Companies, Steelcrete Bldg., Wheeling, W. Va.

ALUMINUM PAINT—An illustrated handbook gives the physical properties of aluminum paint and discusses the opportunities for its use in modern industry. Composition, characteristics, and special properties of aluminum paint are covered in detail.—Aluminum Company of America, Pittsburgh, Pa.

BRAKES—Bulletin 1004 illustrates and describes the E C & M type WB brake for steel mill applications. The method of removing a motor armature and brake wheel is illustrated.—The Electric Controller & Mfg. Co., Cleveland, Ohio.

GEARS—The pocket-size catalog 47 gives specifications and prices on the standardized gears, chains, and speed reducers carried in stock for immediate delivery at the Boston Gear service stations.—Boston Gear Works Sales Co., Norfolk Downs, Quincy, Mass.

TIERING MACHINE—A folder illustrates and gives specifications for the various Standard electric and handpower types of tiering machines.—Standard Conveyor Co., North St. Paul, Minn.

MOTORS—A 16-page booklet illustrates and describes the various Janette standard motors of 1/30 to ½ hp. for alternating or direct current.—Janette Mfg. Co., 556-558 W. Monroe St., Chicago, Ill.

SILENT CHAIN—A circular entitled "Improving Power Transmission" illustrates applications of Ramsey silent-chain drives in industrial plants.—Ramsey Chain Co., Inc., Albany, N. Y.

STEEL STRINGERS—A folder illustrates from photographs and sketches the application of Midwest steel stringers for supporting lineshafts and other overhead equipment.—Midwest Steel & Supply Co., Inc., 100 E. Forty-fifth St., New York, N. Y.

SOLDERING—An interesting 29-page booklet entitled "Facts on Soldering" gives valuable information on fluxes, solders, soldering equipment, and the application of solders and flux.—Chicago Solder Co., Chicago, Ill.